DIRECT SURVIVAL AND INJURY EVALUATION OF JUVENILE CHINOOK SALMON PASSING JOHN DAY DAM SPILLWAY WITH AND WITHOUT A TOP SPILLWAY WEIR (TSW)

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (Corps), Walla Walla, Washington, sponsored an investigation in March 2008 at John Day Dam to assess the survival (direct effects) and condition of Chinook salmon smolts, *Oncorhynchus tschwaytscha*, in passage through Spillbay 16 equipped with a Top Spillway Weir (TSW) and a conventional Spillbay (number 17). Control fish were released into the Juvenile Fish Facility bypass pipe. The primary objectives of the investigation was to evaluate the performance of the TSW at John Day Dam by estimating and comparing direct survival and injury rates of juvenile salmon upon passage through the TSW and Spillbay 17.

Hatchery-reared Chinook salmon smolts were released near mid depth of the discharge jet for both the TSW (elevation 255 ft) and Spillbay 17 (elevation 215 ft) at a spill volume of 9.7 and 6.4 kcfs, respectively. Based on computational fluid dynamics (CFD) modeling, the two release points were sited so the projected path of the fish would be 6.5 and 4 ft above the ogees of the TSW and Spillbay 17. The statistical criterion of the study was to release a sufficient number of fish to be able to detect a 5% difference at $P = 0.05$ level on the survival and injury estimates between the TSW and Spillbay 17 and obtain a precision of $\pm$ 0.025, 95% of the time on the estimates. A limited supplementary test (designated vortex) determined the direct survival and injury on fish passed via a vortex in the forebay of Spillbay 17.

Chinook salmon smolts for this investigation were transported from the Carson National Fish Hatchery, WA to John Day Dam. A total of 571 treatment fish (305 TSW, 241 Spillbay 17, and 25 Spillbay 17 vortex) and 120 control fish were released. The average total length for treatments and control fish was 136 mm.

The recapture rate (physical retrieval of alive and dead fish) ranged from 98.7 to 100% for the standard treatment groups and 100% for the controls. Recapture rate for vortex passed fish was 84%. Retrieval times for individual treatment fish group ranged from 2 to 212 min (average 14 min) compared to about 5.2 min average time for controls. The difference in recapture times was primarily a function of safety considerations; recapture boat crews had to stay at least 500 yds downstream of the turbulent spill discharge.

The 48 h direct survival probabilities were 0.980 (SE= 0.008) for fish released through the TSW, 1.00 (SE=0.0001) for fish released through Spillbay 17 and 0.800 (SE=0.080) for vortex passed fish. Precision (ε) on survival probabilities for the TSW and Spillbay 17 were $\leq \pm$ 0.025, 95% of the time and met the prespecified criterion. The TSW survival estimate (48 h) was significantly less ($P < 0.0313$) than Spillbay 17 and the vortex estimate was significantly less ($P < 0.0375$) than Spillbay 17 estimate.

The Malady-Free Estimate which includes only recaptured fish without maladies (free of passage-related visible injuries, scale loss > 20% per side, and loss of equilibrium) was 0.970 and 0.967 for TSW and Spillbay 17 passed fish, respectively. The conditional Malady-Free Estimates were virtually identical for the TSW (0.970, SE = 0.010) and Spillbay 17 (0.967, SE = 0.012) passed fish. Likewise, the joint probability of 48 h survival and being malady-free estimates were also similar for TSW (0.951, SE = 0.012) and Spillbay 17 (0.967, SE = 0.012) passed fish. However, the malady-free metrics were much lower for the fish passed through the vortex at Spillbay 17 than through the mid-release point at Spillbay 17. The malady-free, conditional malady-free, and joint probability estimates for the vortex passed fish were 0.700 (SE = 0.103) and 0.560 (SE = 0.099), respectively.

The most prevalent injury was eye damage (typically hemorrhaged), which appeared to be inflicted

by shear forces. None of the control fish had injuries.

Fish that likely passed near the middle of the discharge jet flowing over the TSW or under the tainter gate in Spillbay 17 had high direct survival (> 98%) and most (> 95%) were free of any passage inflicted maladies; these passage rates appear to be relatively benign. However the limited number of fish passed through a vortex in Spillbay 17 indicated this passage route may not be benign.

The results of the present investigation are applicable for fish passing near the middle of the TSW and Spillbay 17 discharge jets; however, some other studies have shown that fish passing deep in the spillway discharge may suffer higher injury/mortality rate than those passing higher in the discharge. Since fish were not released deep in the spillbay discharge at the John Day Dam, the fate of deep entrained fish is unknown.

Survival Study Summary Framework

Year: 2008

Study site(s): John Day Dam Spillbays 16 (TSW) and 17

Objective(s): Evaluate the performance of a Top Spillway Weir (TSW) by estimating and comparing direct survival/injury of juvenile salmon passed through a TSW and conventional spillbay.

State hypothesis, if applicable:

Fish
- Species (race): Chinook salmon (spring)
- Source: Carson National Fish Hatchery

Size (range and mean)
- Weight: Not taken
- Length: 105-157 mm total length, mean = 136 mm

Tag
- Type/model: HI-Z (balloon) Tags and Advanced Telemetry radio tags
- Weight (gm): HI-Z = 1.9 gm, radio tags = 1.0 gm

Implant procedure
- Externally attached and then detached upon fish recapture

Survival estimate (per species or objective) – 48 h direct
- Type (project, *etc.*): TSW and Spillbay 17, approximately mid jet passage, also vortex in Spillbay 17
- Value (SE): TSW 0.980 (SE = 0.008) Spillbay 17 1.000 (< 0.0001), vortex 0.800 (0.080)
- Sample size/replicate: TSW 305, Spillbay 17 241, Vortex 25, Control 120
- Analytical model: Joint likelihood model (Normandeau Associates and Skalski 2005)

Conditional malady-free estimates (per species or objective) – 48 h direct
- Value (CFE) TSW = 0.970 (SE = 0.001), Spillbay 17 = 0.967 (SE = 0.012), Vortex = 0.700 (SE = 0.103)

Hypothesis tests and results (if applicable)
- H_o: Injury/48 h survival of TSW and Spillbay 17 are equal for mid passed fish
- H_a: Injury/48 h survival of TSW and Spillbay 17 are not equal for mid passed fish
- H_o: Injury/48 h survival of Spillbay 17 vortex passed fish are equal to mid passed fish
- H_a: Injury/48 h survival of Spillbay 17 vortex passed fish are not equal to mid passed fish
- Conclusion: Survival rate of TSW passed fish was significantly ($P < 0.05$) lower than for Spillbay 17 passed fish
- Malady-free rates of TSW passed fish were similar to Spillbay 17 passed fish
- Both survival and malady-free rates were much lower for vortex passed fish than for mid Spillbay 17 passed fish

Characteristics of estimate
- Effects reflected (direct, total, *etc.*): Direct
- Absolute or relative: Absolute (relative to control)

Environmental/operating conditions • Relevant discharge indices: TSW, 9.7 kcfs; Spillbay 17, 6.2 kcfs; Spillbays 14-18 opened, total spill 29 kcfs • Temperature: 6.0°C • Treatment(s): TSW fish released so they passed 6.5 ft above crest; and Spillbay 17 fish released so they passed 4 ft above crest. Spillbay 17 vortex fish released into vortex in forebay
Unique study characteristics: Direct survival (48 h) for TSW fish was 0.98 and significantly lower ($P < 0.05$) than for Spillbay 17 fish. Fish injury (malady) metrics indicated no statistical difference between TSW and Spillbay 17 fish. A limited (25) release of fish into a vortex in forebay at Spillbay 17 indicated this passage route is not benign.

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1.0 INTRODUCTION AND BACKGROUND

The U.S. Army Corps of Engineers (USACE) has been striving to improve the salmon production and fish passage at Federal Columbia River Power System (FCRPS) projects for several decades. These improvements have resulted in a number of structural and operational changes that have improved survival of migrating fish passing through the system. Current emphasis is to maintain high levels of fish passage efficiency (non-turbine passage). One promising strategy to bolster fish passage efficiency and survival rates is through providing a surface flow passage outlet by equipping spillbays with Removable Spillbay Weirs (RSW) and/or Top Spillbay Weirs (TSW) (Figures 1-1 and 1-2). Both RSW(s) and TSW(s) have been successfully deployed and tested at multiple Columbia and Snake River FCRPS projects (Table 1-1). These RSW(s) and TSW(s) provide a surface zone of influence (ZOI) that juvenile salmonids readily discover, particularly when the surface flow ZOI is in proximity to powerhouse attraction flows. The relation between high levels of water flow and fish attraction at these projects has been demonstrated to be integral in the success of these and other surface flow bypass systems.

This study reports on the condition of recaptured juvenile Chinook salmon passed through a newly installed TSW at John Day Dam (JDA). The primary goal of this study at JDA was to evaluate the performance of the TSW by estimating and comparing the direct effects of passage through Spillbay 16 equipped with a TSW to a conventional spillbay (17) on direct survival (1 and 48 h) and injury rates of juvenile salmon. The National Marine Fisheries Service (NMFS) and the regional salmon managers require direct injury and survival tests for prototype structures. The HI-Z Turb'N Tag (HI-Z Tag) recapture technique has been used to ascertain the direct effects of passage of all the Corp's RSW(s) and TSW(s) prior to their use for passing ESA-listed salmonids (Normandeau Associates *et al*. 2002, 2008; Normandeau Associates and Skalski 2006). The HI-Z tag recapture technique (Heisey *et al*. 1992; Mathur *et al*. 1999) facilitates quick retrieval of fish after passage through power station passage routes and allows for immediate assessment of fish condition and injury type.

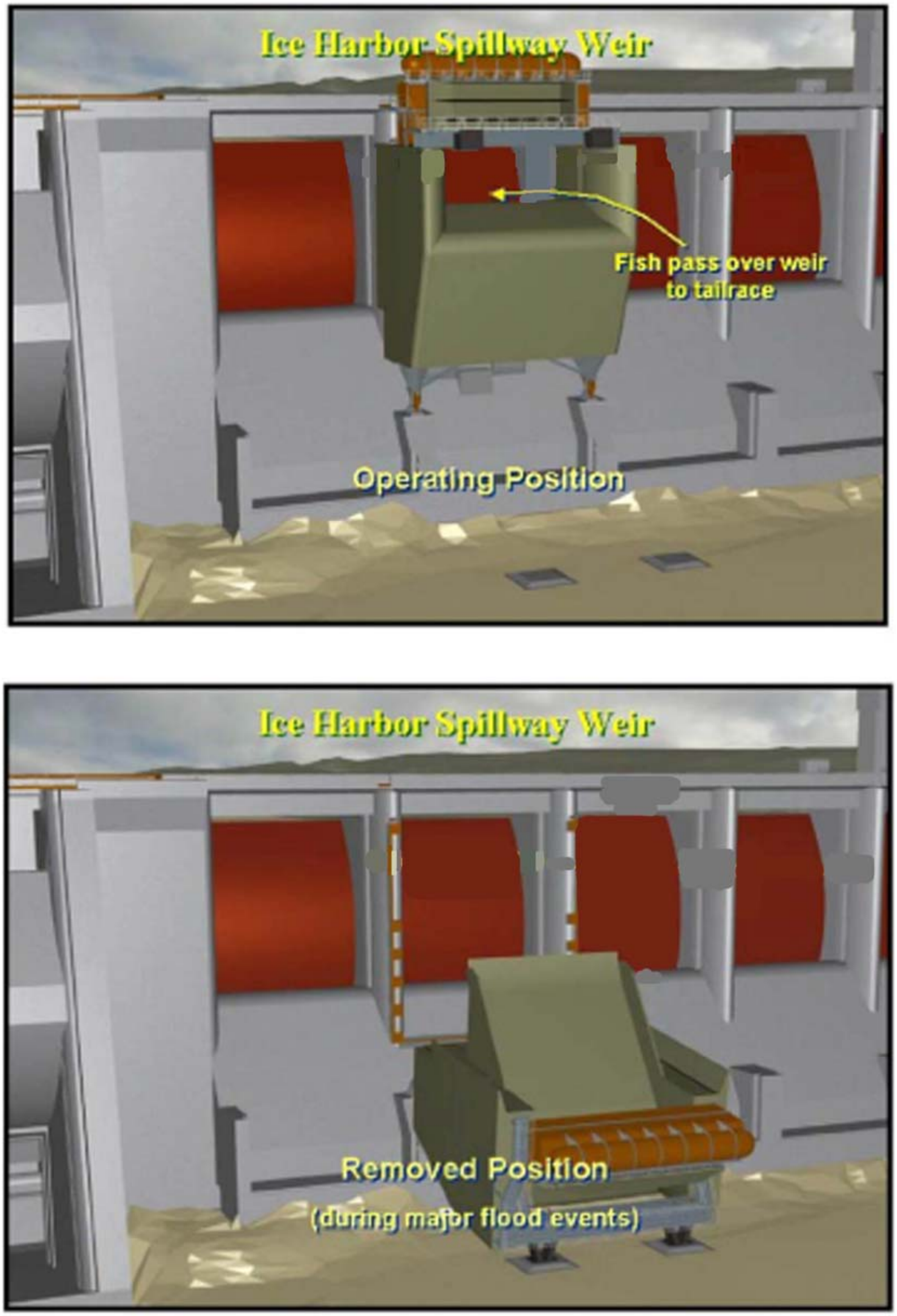


Figure 1-1 Schematic view of a Removable Spillbay Weir (RSW) in the operating and removed positions.

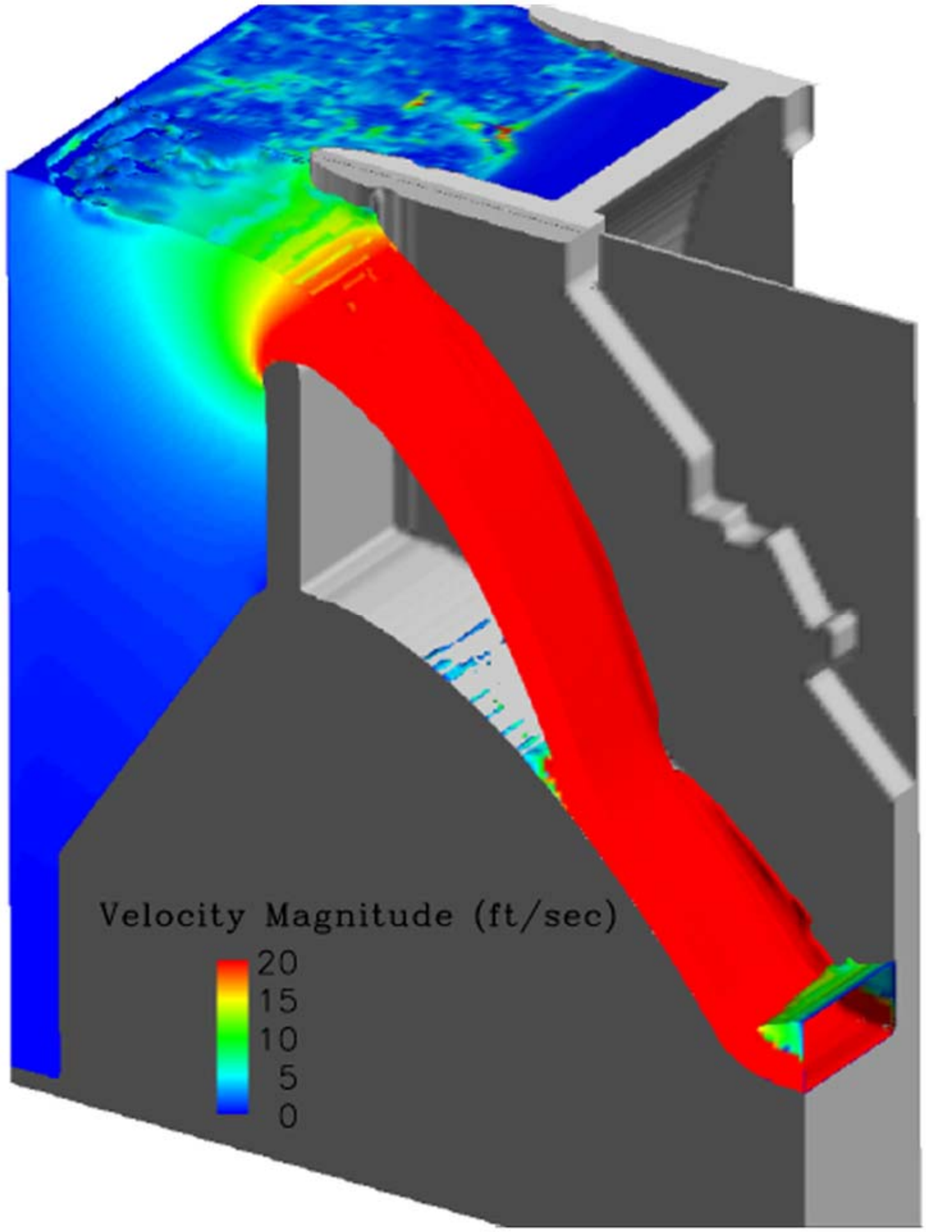


Figure 1-2 Schematic of Top Spillbay Weir (TSW).

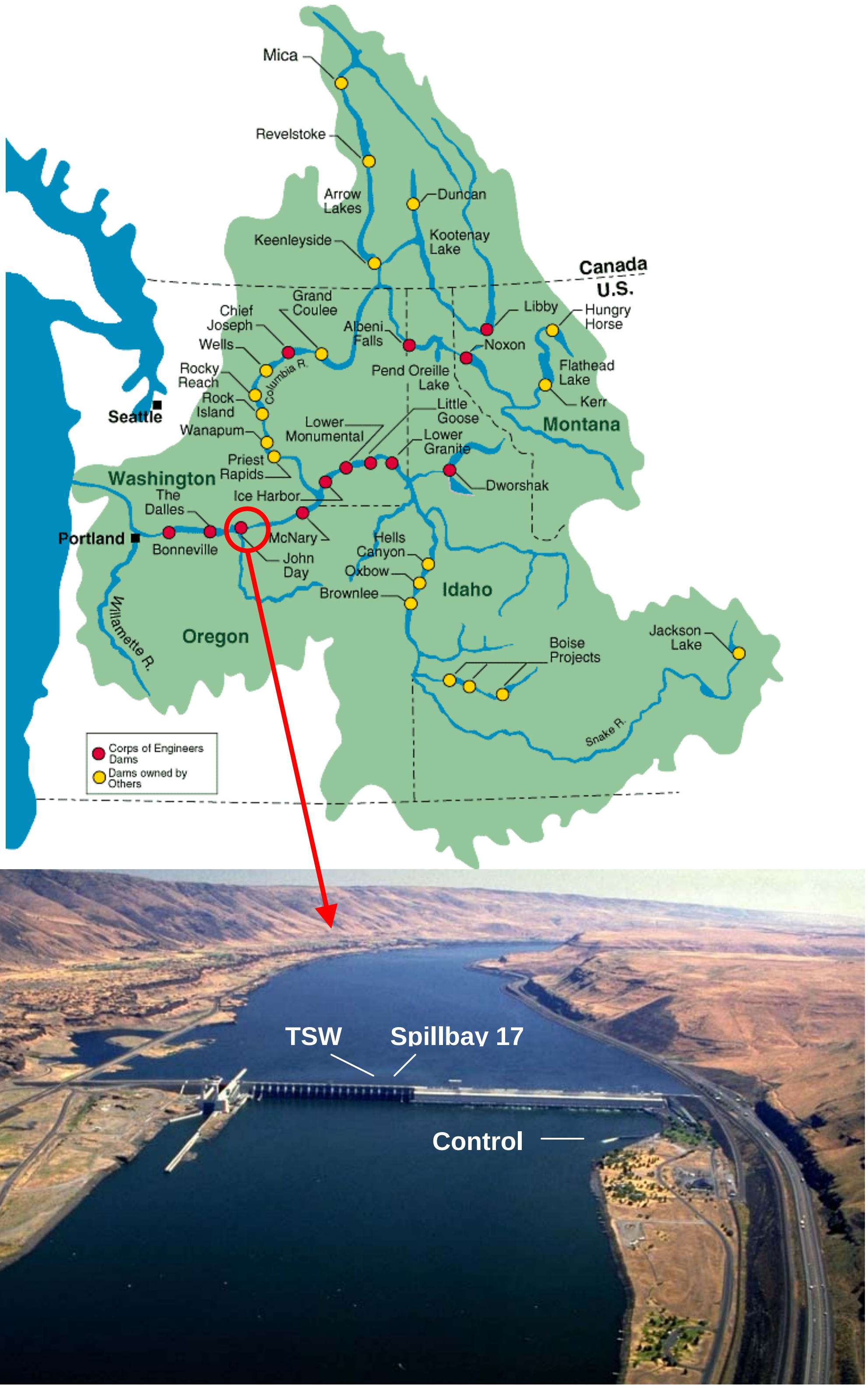


Figure 1-3 **General location and layout of John Day Dam showing treatment and control fish release locations, March-April 2008.**

1.1 Study Objectives

The primary goal of the TSW evaluations at JDA in 2008 was to assess the performance of the TSW by estimating and comparing the direct effects of passage through Spillbay 16 (TSW) to Spillbay 17 (conventional) on direct survival (1 and 48 h) and injury rates of juvenile salmon at one test elevation per spillbay. Sufficient number of fish were to be released such that a statistical difference of ± 5%, 95% of the time was detectable between survival and injury rates between spillbays and precision (ε) on resulting estimates was to be within ± 0.025, 95% of the time.

Table 1-1

Water depths, flow deflectors, and stilling basin characteristics of John Day, NcNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams on the Columbia and Snake Rivers. Source: U.S. Army Corps of Engineers.

	John Day	McNary		Ice Harbor		Lower Monumental		Little Goose	Lower Granite
Spillbays	**16* and 17**	**20***	**21 and 22***	**1**	**2*, 3, and 5**	**7**	**8***	**1, 2, and 3**	**1*, 2**
Water Depths									
Minimum tailwater (fmsl)	155	262	262	337	337	437	437	537	633
Spillway crest elevation (fmsl)	210	291	291	391	391	483	483	581	681
Minimum forebay (fmsl)	262	335	335	437	437	537	537	633	733
Maximum forebay (fmsl)	265	340	340	440	440	540	540	638	738
Stilling basin invert (fmsl)	114	228	228	304	304	392	392	466.5	580
Min tailwater to spillway crest (ft)	55	29	29	54	54	46	46	44	48
Min forebay to spillway crest (ft)	52	44	44	46	46	54	54	52	52
Min tailwater to deflector (ft)	7	6	6	3	-1	3	3	5	3
Min tailwater to stilling basin invert (ft)	41	34	34	33	33	45	45	70.5	53
Flow Deflectors									
Elevation of lip (fmsl)	148	256	256	334	338	434	434	532	630
Radius (ft)	15	0	15	15	15	None	15	None	15
Deflection angle (°)	45	43	43	55	55	45	45	45	45
Deflector to basin (ft)	34	28	28	30	34	42	42	65.5	50
Horizontal section length (ft)	12.5	12.5	12.5	12.5	12.5	12.5	12.5	8	12.5
Stilling Basin									
Length from deflector (ft)		283.9	283.9	181.4	181.4	224.5	224.5	136	238.5
Volume at min tailwater (ft^3)	485,000**	551,000**	551,000**	327,000	327,000	518,000	518,000	573,000	638,000
Baffle block type (ft)	12 Perp	15.5 Perp	15.5 Perp	8 Perp	8 Perp	N/A	N/A	Roller bucket w/dentates	N/A
End sill to baffle block (ft)	63 and 88	90 and 135	90 and 135	42	42	N/A	N/A	20	N/A

* Spillbays with a TSW or RSW

** Single bay, centerline between piers, simple rectangular shapes (not subtracting for ogee slope, transitions, or baffle blocks)

1.2 Site Description

The JDA Project, Washington, is located on the Columbia River at River Mile 215.6, approximately 24 miles upstream of The Dalles Dam (TDA). The JDA project is the third to last dam encountered by juvenile migrants on their journey to the Pacific Ocean and forms a 76-mile slack-water impoundment to McNary Dam (Figure 1-3). The JDA project includes a powerhouse, spillway, navigation lock, and fish passage facilities. The structure is primarily a concrete gravity dam with a north abutment embankment section. It is a storage project and the dam can be manipulated to provide additional flood control for the lower river. The normal operating pool elevation during fish passage season typically fluctuates from elevation 262 to 265 feet mean sea level (fmsl). The operating range of the project varies from elevation 257 to 268 (fmsl). The project is multipurpose and provides hydropower, navigation, flood control, and recreational benefits.

Maintaining high levels of fish passage efficiency (non-turbine passage) is currently being emphasized for the operation of Federal Columbia River Power System (FCRPS) projects. Providing a surface flow route of passage in concert with adequate attraction allows fish the opportunity for discovery and passage, thereby decreasing powerhouse passage rates. By exploiting the natural surface orientation of migrating juvenile salmonids, it is anticipated that the TSW installed in Spillbay 16 could be an effective strategy at JDA, where juvenile migrants have been extensively documented displaying lateral searching and milling behaviors across the powerhouse and spillway.

2.0 STUDY DESIGN

The study was designed to compare direct fish survival and injury rates between the TSW and Spillbay 17 at one entrainment depth (Table 2-1, Figures 1-1 and 2-1). There was also one release of juvenile Chinook salmon into the vortex of Spillbay 17 (4 April), so this group was analyzed and compared separately. This vortex release was compared to the other two treatments only for that last day of releases.

Maximum likelihood estimates and analysis of deviance (ANODEV) were used to estimate 1 h and 48 h passage survival and malady-free rates and compare the rates between the spillbays with and without TSW.

Table 2-1 Schematic of the spillway trials indicating blocks and spillbays (treatment), for juvenile Chinook salmon, John Day Dam, March-April 2008.

Block	Date	Spillbay 16 (TSW)	Spillbay 17 (Conventional)	Spillbay 17 (Vortex)
1	3/31	x	x	
2	4/01	x	x	
3	4/02	x	x	
4	4/03	x	x	
5	4/04	x	x	x

The two test conditions were evaluated using ANODEV for a randomized block design (Table 2-2).

Table 2-2 Degrees-of-freedom table for the randomized block design comparing passage through TSW installed and Spillbay 17 for juvenile Chinook salmon, John Day Dam, March-April 2008.

Source	DF	*F*-test
$Total_{Cor}$	9	
Blocks	4	
Treatments	1	$F_{1,4}$
Error	4	

Sufficient number of fish were to be released to detect a statistical difference of ± 5%, 95% of the time for direct survival and injury rates between the test conditions and obtain these rates within ± 0.025, 95% of the time. Two additional metrics of post-passage fish condition were also incorporated into the study design to provide a more comprehensive assessment of fish capture data. These were: estimation of conditional probability of fish being malady-free given alive at 48 h, and estimation of joint probability of 48 h survival and being malady-free. Malady-free was defined as a fish being free of visible injuries, scale loss (≤ 20% per side), and/or loss of equilibrium.

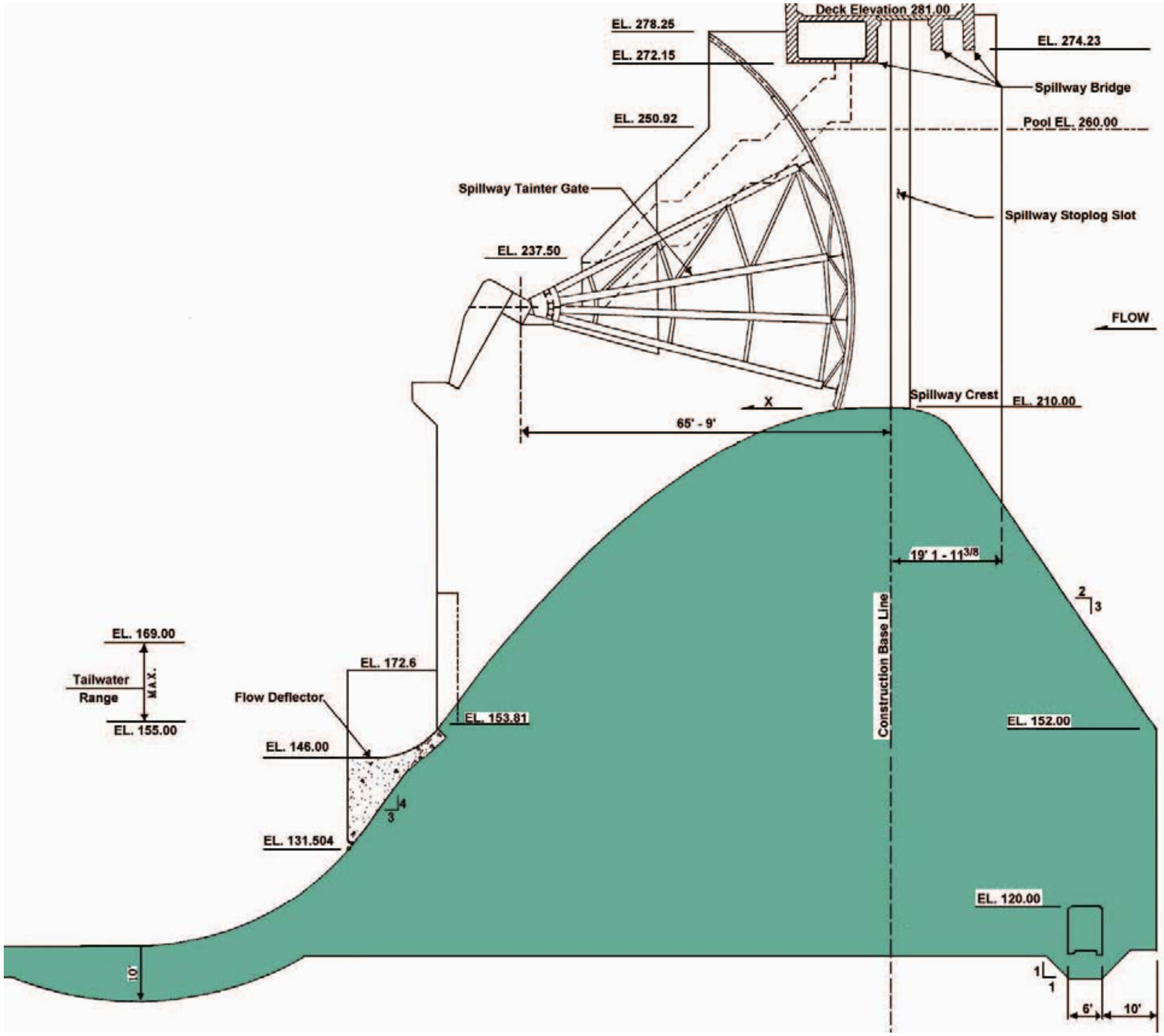


Figure 2-1 Cross section of a conventional spillbay, John Day Dam (Provided by PNNL).

Based on computational fluid dynamics (CFD), fish were released so they were projected to pass 6.5 ft above the crest of the TSW and 4.0 ft above the crest of the Spillbay 17 (Figure 2-2 and 2-3). These release locations were projected to position the fish near mid jet above the spillbay crest for both the TSW and Spillbay 17.

Spill volume through the TSW and Spillbay 17 was maintained near 9.7 and 6.2 kcfs, respectively. Table 2-3 provides average flow and tailwater conditions during the investigation. Appendix Table A provides the daily station parameters recorded during passage and condition of juvenile Chinook salmon released during this investigation.

Overall, the study followed the guidelines and recommended protocols for conducting, analyzing, and reporting juvenile Chinook salmonid survival studies in the Columbia River Basin (Peven *et al.* 2005).

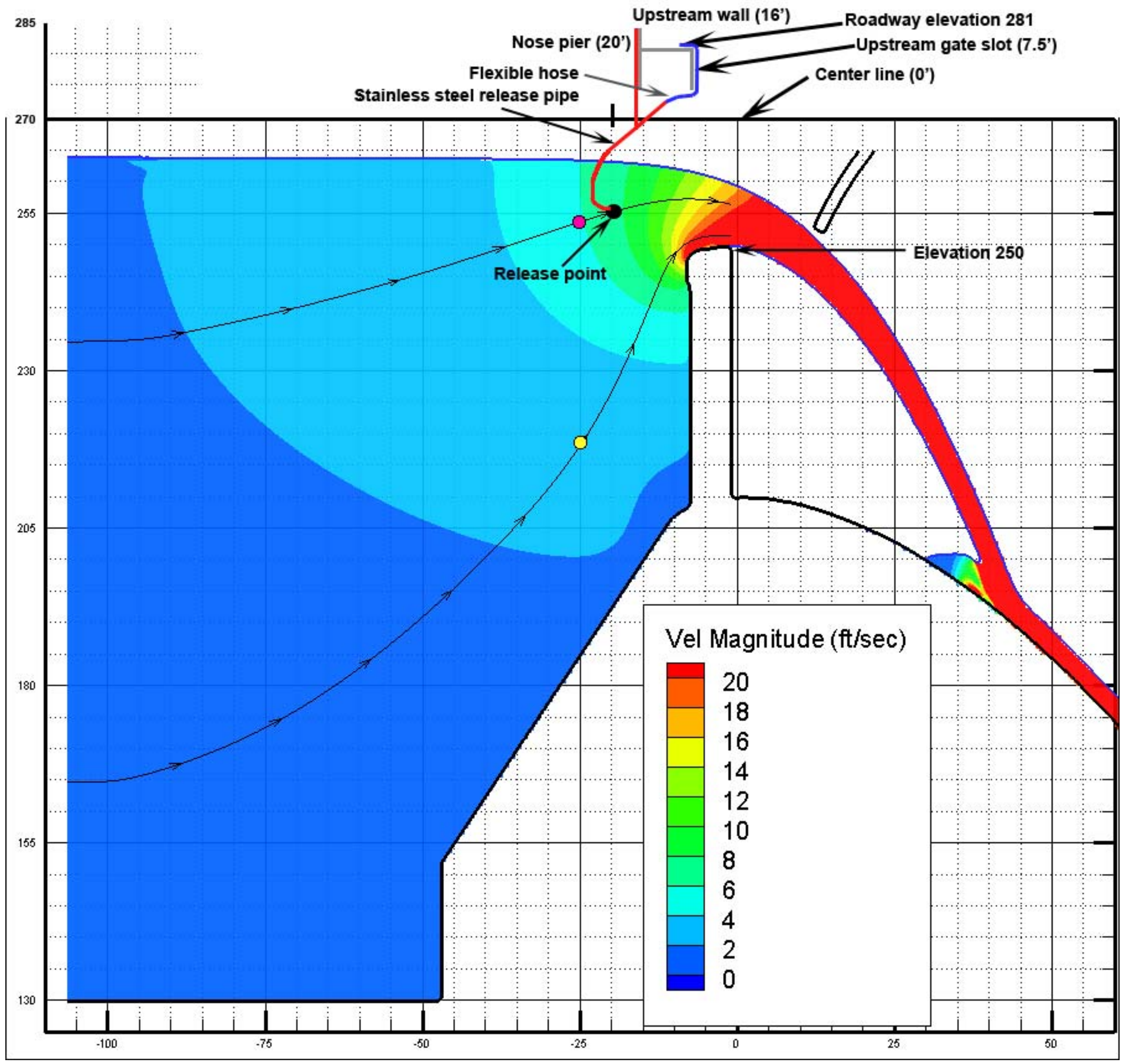


Figure 2-2 Pipe deployment at TSW to release fish in a velocity field of approximately 7 ft/sec, 20 ft upstream of spillbay center line (crest of spillbay) and at an elevation of 255 fmsl. This release point was projected to take fish 6.5 ft above the TSW crest at John Day Dam.

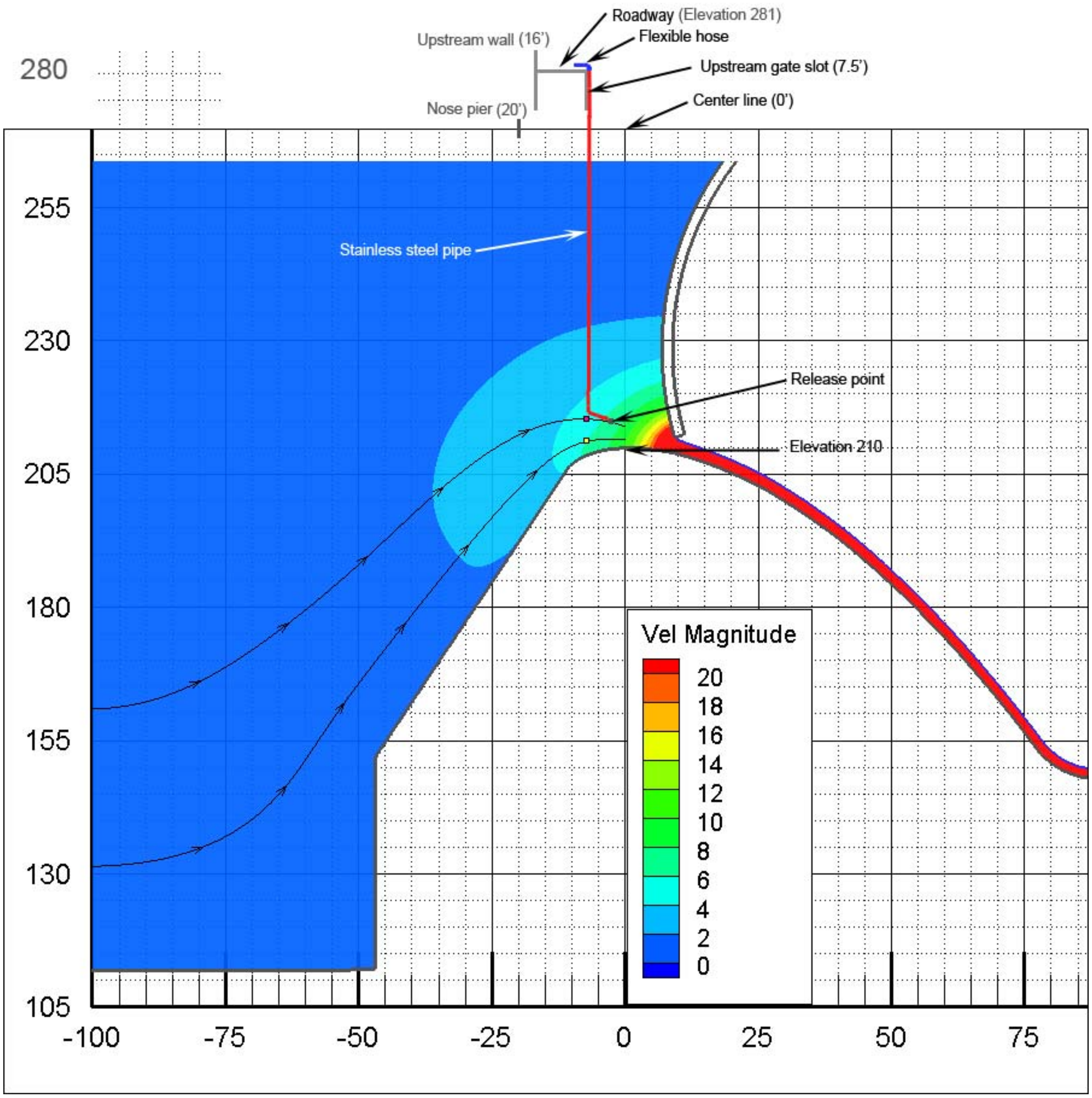


Figure 2-3 Pipe deployment of Spillbay 17 to release fish in a velocity field of approximately 7 ft/sec, 2.5 ft upstream of spillbay center line (crest of spillbay) and at an elevation of 215 fmsl. This release point was projected to take fish 4 ft above crest of spillbay at John Day Dam when gate was opened 4.5 ft stops (36 ft) resulting in 6,200 cfs discharge.

Table 2-3

Station parameters (averages for each scenario) recorded during the survival/condition investigation of juvenile Chinook salmon passed at mid depth through TSW and Spillbay 17. Control fish were released via the Juvenile Fish Facility bypass pipe at John Day Dam, March-April 2008.

Release Location	Number Released	Forebay Elevation (fmsl)	Tailwater Elevation (fmsl)	Head (fmsl)	Turbines: No. Operating	Turbines: Total kcfs	Spillbays (kcfs): 14	15	16	17**	18	Total Spill (kcfs)
Spillbay 16												
Mid	305	264.1	159.2	104.9	8	123.8	1.6	9.4	9.7	6.2	2.4	29.2
Spillbay 17												
Mid	241	264.2	159.4	104.8	9	135.4	1.6	9.2	9.7	6.2	2.4	29.1
Spillbay 17*												
Vortex	25	263.8	159.0	104.8	8	122.2	1.6	9.6	9.6	6.2	2.4	29.4
Control	120	263.9	159.2	104.8	8	126.1	0.3	5.6	8.8	1.1	0.4	16.2

* Fish released at surface into vortex in forebay of Spillbay 17
** Spillbay opened (4.5 stops ft resulting in 6.2 kcfs discharge (3.6 ft)

2.1 Sample Size

Fish releases were apportioned between the two spillbays to provide a sufficient number to (1) achievement of prespecified precision (ε) level of ≤ ± 0.025, 95% of the time on the survival ($\hat{\tau}$) and fish free of passage related maladies; and (2) to detect prespecified differences (Δ) of 0.05, 95% of the time between the two survival or malady-free estimates with a statistical power defined as 1-β. Beta (β) is the probability that the statistical test fails to reject the null hypothesis where the alternative hypothesis is true; 1-β is the statistical power of the test. In the proposed study, the null hypothesis (H_o) is that the survival or malady-free estimates (MFE) with the Top Spillbay Weir (TSW) is greater than that without the TSW (H_o: $\hat{\tau}$ or MFE TSW ≥ $\hat{\tau}$ or MFE without TSW) versus the alternative hypothesis (H_α) that survival or malady-free estimate is not improved by TSW (H_α: $\hat{\tau}$ or MFE TSW < $\hat{\tau}$ or MFE without TSW).

The sample size requirements per treatment condition are presented in Tables 2-4 and 2-5. In general, the sample size is a function of the recapture rate (P_A), expected passage survival ($\hat{\tau}$) or malady-free rate, the survival/malady-free rate of control fish (S), and the desired precision of difference (Δ) to be detected at a given probability of significance (α). Sample size requirements decrease with an increase in survival/malady-free and recapture rates, or detection of a larger difference (Δ). Only precision (ε), α, and the magnitude of the difference (Δ) to be detected with a given power (β) level can strictly be controlled by an investigator. Figure 2-4 shows an example of the dependence of sample size on recapture rate, control survival, and the desired precision (ε).

Assuming a control survival or malady-free rate of 0.99 and a recapture rate of 0.98, approximately 300 fish per treatment condition is needed for detecting difference of 0.05 (τ_1 = 0.99 and τ_2 = 0.94) between the two treatment conditions at (α) = 0.05 and power (β) = 0.20 (Table 2-4). Sample sizes needed to attain a precision (ε) of ≤ ± 0.025, 95% of the time on survival and malady-free estimates are shown in Table 2-5. Initially, we allocated approximately 700 fish; 300 for each treatment condition and 120 controls for this study (Table 2-6). These allocations of fish were construed as guidelines because the embedded flexibility in the HI-Z tag-recapture technique permits adjustment of sample sizes as the investigation progresses. Thus, during the investigation, if the observed results for any of the treatment conditions were contrary to initial expectations, sample sizes could be adjusted with Corps approval to achieve the desired statistical precision level.

Table 2-4

Required sample sizes for detecting a statistical difference (Δ = treatment 1 minus treatment 2) of 0.05 between two survival[1] estimates at α = 0.05 and (1 - β) = 0.80.

Proportion of controls alive	Proportion alive Treatment 1	Treatment 2	Difference Δ	Probability of recapture alive 0.95	0.98	0.99
1.00	0.99	0.94	0.05	416	262	213
	0.97	0.92	0.05	501	350	302
	0.95	0.9	0.05	582	434	387
0.99	0.99	0.94	0.05	467	311	261
	0.97	0.92	0.05	550	398	350
	0.95	0.9	0.05	630	481	434
0.98	0.99	0.94	0.05	518	361	311
	0.97	0.92	0.05	601	447	398
	0.95	0.9	0.05	680	529	481
0.97	0.99	0.94	0.05	571	413	362
	0.97	0.92	0.05	653	498	448
	0.95	0.9	0.05	731	579	530
0.96	0.99	0.94	0.05	625	465	414
	0.97	0.92	0.05	706	549	499
	0.95	0.9	0.05	782	629	580

[1] Table values also are applicable for detecting differences between malady-free estimates.

Table 2-5

Required sample size if control survival is 1.00, 0.99, or 0.98, recapture rate is 0.99, 0.98, or 0.95 and expected survival[1] of treatment fish passed is 0.90, 0.95, and 0.97 to achieve a precision level (ε) of ≤ ± 0.025, 95% of the time.

	Expected Survival ($\hat{\tau}$)		
Control Survival	**0.95**	**0.97**	**0.99**
		Recapture Rate = 0.99	
1.00	287	210	130
0.99	369	294	217
0.98	453	381	305
		Recapture Rate = 0.98	
1.00	370	295	217
0.99	453	381	305
0.98	537	468	395
		Recapture Rate = 0.95	
1.00	628	562	492
0.99	714	650	583
0.98	801	740	676

[1] Table values also applicable for malady-free estimates.

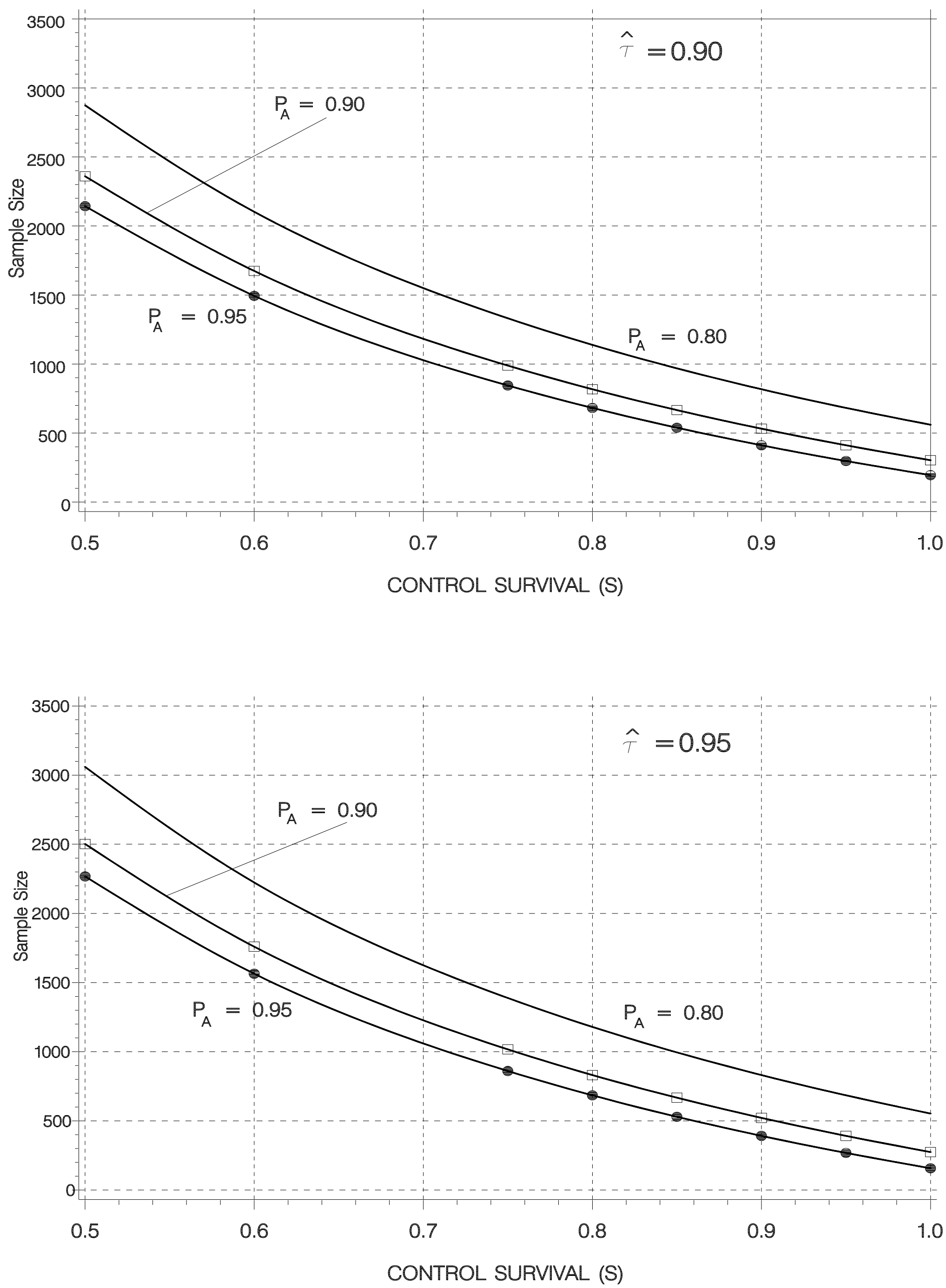


Figure 2-4 Example of sample size dependence on control fish survival (S) and recapture rates (P_A) to achieve precision (ε) of 0.05 at 1-α = 0.90 for two expected survival rates ($\hat{\tau}$).

Table 2-6

Daily schedule of releases of juvenile Chinook salmon and sensor fish into TSW and Spillbay 17 at mid depth. Control fish released via Juvenile Fish Facility (JFF) bypass pipe at John Day Dam, March-April 2008.

		Passage Location									
		Spillbay 16		Spillbay 17				Control			
		Mid		Mid		Vortex*		(JFF)			
Date	Water Temp (°C)	Fish	Sensor	Fish	Sensor	Fish	Sensor	Fish	Sensor	Fish Total	Sensor Total
31-Mar	7.0	5		5				5		**15**	**0**
1-Apr	6.0	73	8	68	8			30	1	**171**	**17**
2-Apr	6.5	84	8	73	7			30	1	**187**	**16**
3-Apr	6.5	99	15	75	9			30	1	**204**	**25**
4-Apr	6.5	44	2	20	6	25	5	25		**114**	**13**
Total		**305**	**33**	**241**	**30**	**25**	**5**	**120**	**3**	**691**	**71**

* Fish released at surface into vortex in forebay of Spillbay 17

2.1.1 Sensor Fish

Normandeau assisted Pacific Northwest National Laboratory (PNNL) with the release and recapture of 71 HI-Z-tagged 'sensor packages' passed through TSW and Spillbay 17 under the same conditions and timing as live fish (Table 2-6). Generally, one sensor fish was released for every 10 live fish to gather hydraulic data (Figure 2-5).

2.2 Fish Release System

Treatment fish were released into the TSW, Spillbay 17 (Figure 2-6), and control fish were released into the tailrace through the Juvenile Fish Facility bypass pipe (Figure 2-7). Treatment and control fish were released through an induction system attached to a four-inch diameter flexible hose (Figure 2-7). The flexible hose for the treatment release was coupled to a four-inch stainless steel pipe. The terminus of each release pipe was positioned so the ambient water velocity past the pipe was approximately 5-8 ft/sec (Figures 2-2 and 2-3). Additionally, the terminus of each pipe was positioned based on Corp provided CFD analysis, so fish were projected to pass 6.5 ft (mid) above the TSW and 4.0 ft (mid) above the crest of Spillbay 17. These requirements specified special bends to the release pipes, particularly for the TSW (Figure 2-8). The stainless steel pipes was positioned near the middle of both spillbays and secured with guide wires and/or brackets to ensure each delivery hose remained at the correct depth, was oriented downstream, and would not be drawn into the TSW or spill gate (Figure 2-6). The inside of the stainless steel pipes was thoroughly inspected to insure no rough spots were present that could potentially injure fish.

2.3 Source and Maintenance of Test Specimens

Juvenile Chinook salmon were transported from the Carson National Fish Hatchery, near Bingen, WA via a tank-truck to the project site and held in 200 or 600 gal capacity circular tanks. The transport tank was equipped with a recirculation system and supplemental oxygen supply. Approximately 1,000 fish were transported in a single trip. The approximate fish transportation time was two hours. Upon arrival at the site, fish were acclimated by gradually tempering the transport tank water temperature to the ambient river temperature. This process took approximately 20 min before fish were released into the supply tanks for this investigation. Fish were held a minimum of 24 h prior to tagging to alleviate handling and transport stress, and to allow them to acclimate to ambient river conditions at JDA. Ambient river temperatures ranged from 6.0 to 7.0°C (42.8 to 44.6°F) during the study (Table 2-6).

The treatment and control fish for a given day were randomly drawn from the holding tank thereby assuring that all treatment and control groups were of a similar size and condition. Figure 2-9 shows the total length frequency distribution of treatment and control fish groups. Average lengths of TSW, Spillbay 17 and control fish were 137, 135, and 136 mm, respectively. Fish ranged from 105 to 157 mm in length.

The condition of fish that passed Spillbay 17 via a vortex in the forebay was evaluated by hand dropping fish into the vortex (Figure 2-10). Fish were dropped a maximum height of 16 ft. Control fish were not injured when dropped from similar heights in other studies (Normandeau *et al*. 1997, Normandeau and Skalski 2007).

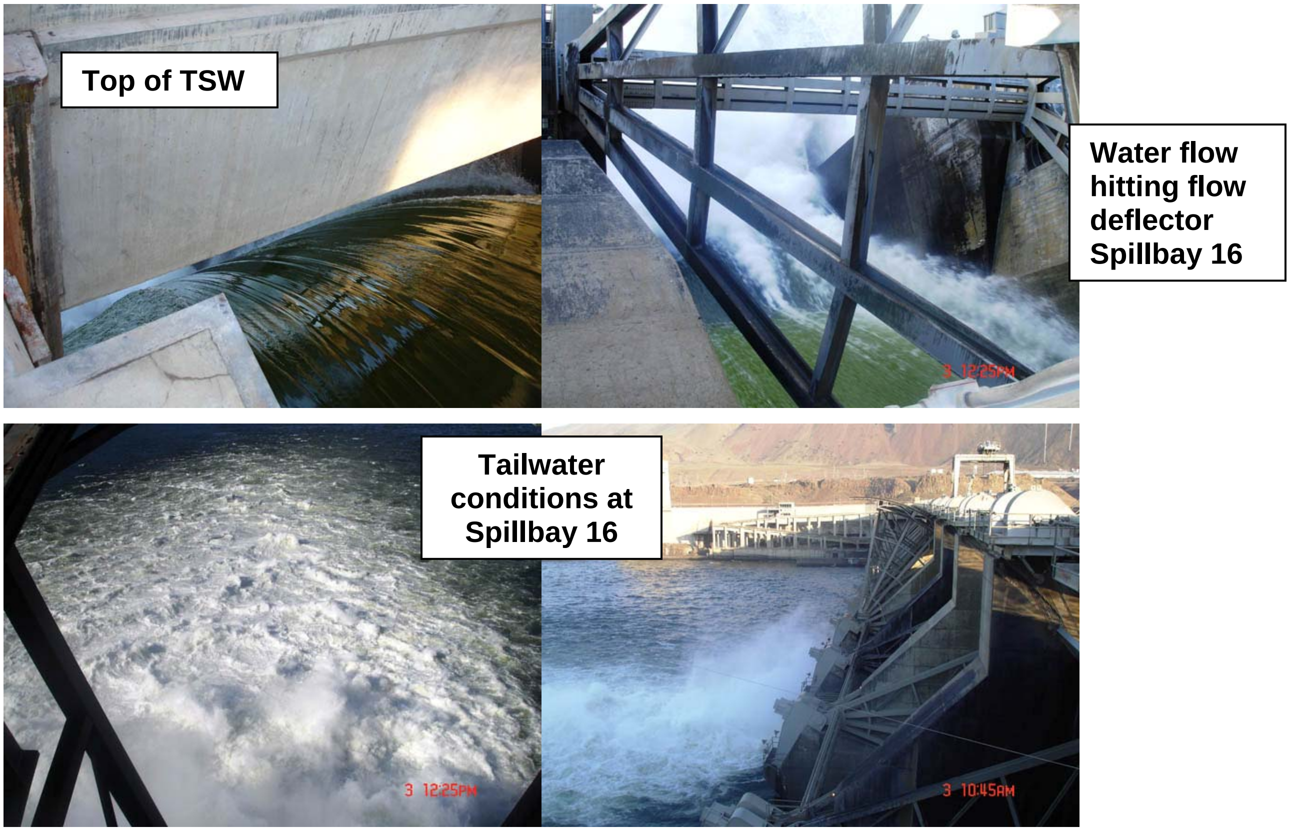


Figure 2-5 Hydraulic conditions at TSW during direct survival/injury test at John Day Dam, March-April 2008.

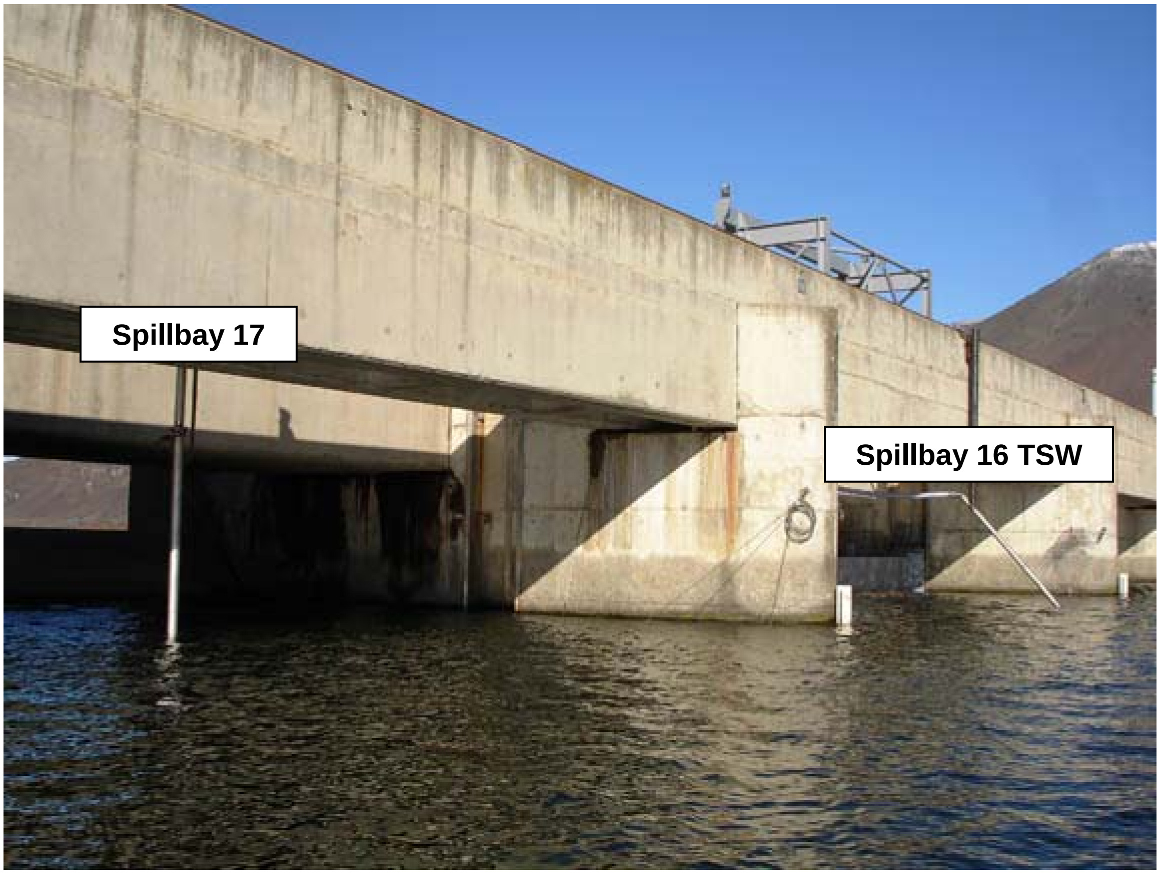


Figure 2-6 Location of treatment release pipe in TSW and Spillbay 17 at John Day Dam, March-April 2008.

Figure 2-7 Release location for control fish released via the John Day Dam Juvenile Fish Facility bypass pipe, March-April 2008.

Figure 2-8 Deployment of stainless steel release pipes in TSW (top) and Spillbay 17 (bottom) at John Day Dam, March-April 2008.

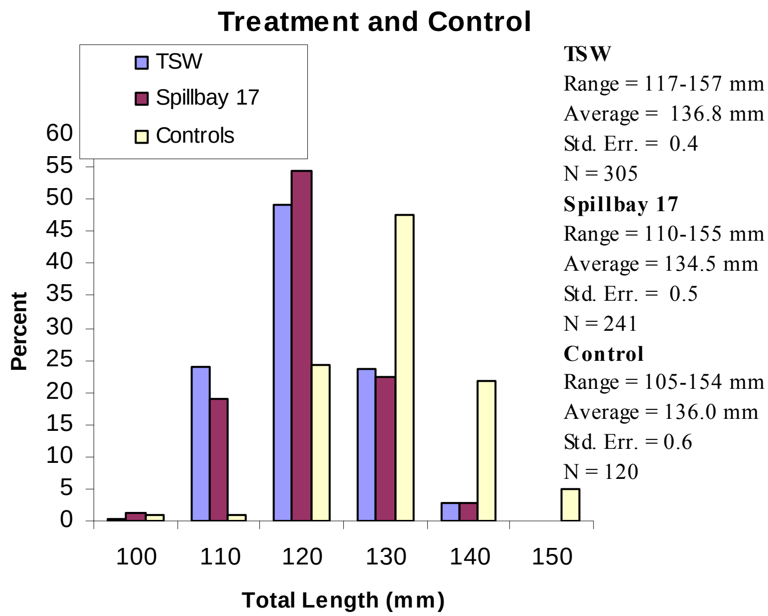


Figure 2-9 Total length (mm) frequency distribution of all treatment and control juvenile Chinook salmon passed through Figure 2-9 and Spillbay 17 at mid depth. Control fish released via the Juvenile Fish Facility bypass pipe at John Day Dam, March-April 2008.

2.4 Tagging and Release

Fish handling and HI-Z tagging techniques followed those used during previous spillway studies (Normandeau Associates 2006; Normandeau Associates and Mid Columbia Consulting Inc. 2001; Heisey *et al.* 1992; Mathur *et al.* 1996, 1999; Normandeau Associates *et al.* 1996, 2008). Lots of 5 to 10 fish were randomly removed from holding tanks to the adjacent tagging site using a water sanctuary equipped net. Fish displaying abnormal behavior, severe injury, fungal infection, or descaling (≥ 20% per side) were not used. The same fish selection criteria was applied to all treatment and control groups. Fish were anesthetized and equipped with two uninflated HI-Z tags and one miniature radio tag.

The tags were attached via a stainless steel pin inserted through the musculature beneath the dorsal and adipose fins. A uniquely numbered VI tag (Visual Implant), was also inserted in the post ocular tissue for use in tracking 48 h survival of individual recaptured fish. Fish also received a fin clip in the event the VI tag became dislodged.

Prior to release through an induction apparatus, fish were allowed to recover from anesthesia. Recovery time generally lasts a minimum of 20 minutes. Fish were placed individually into the induction system holding tub, tags activated, and fish released. The inflation time of the tags could be adjusted slightly by varying the temperature and amount of water injected into tags prior to release. All procedures used in handling, tagging, release, and recapture of fish for all release groups were identical. Approximately 180 fish in lots of 10 to 35 were released throughout the day to evaluate the two treatment conditions (Table 2-6, Appendix Table B-1).

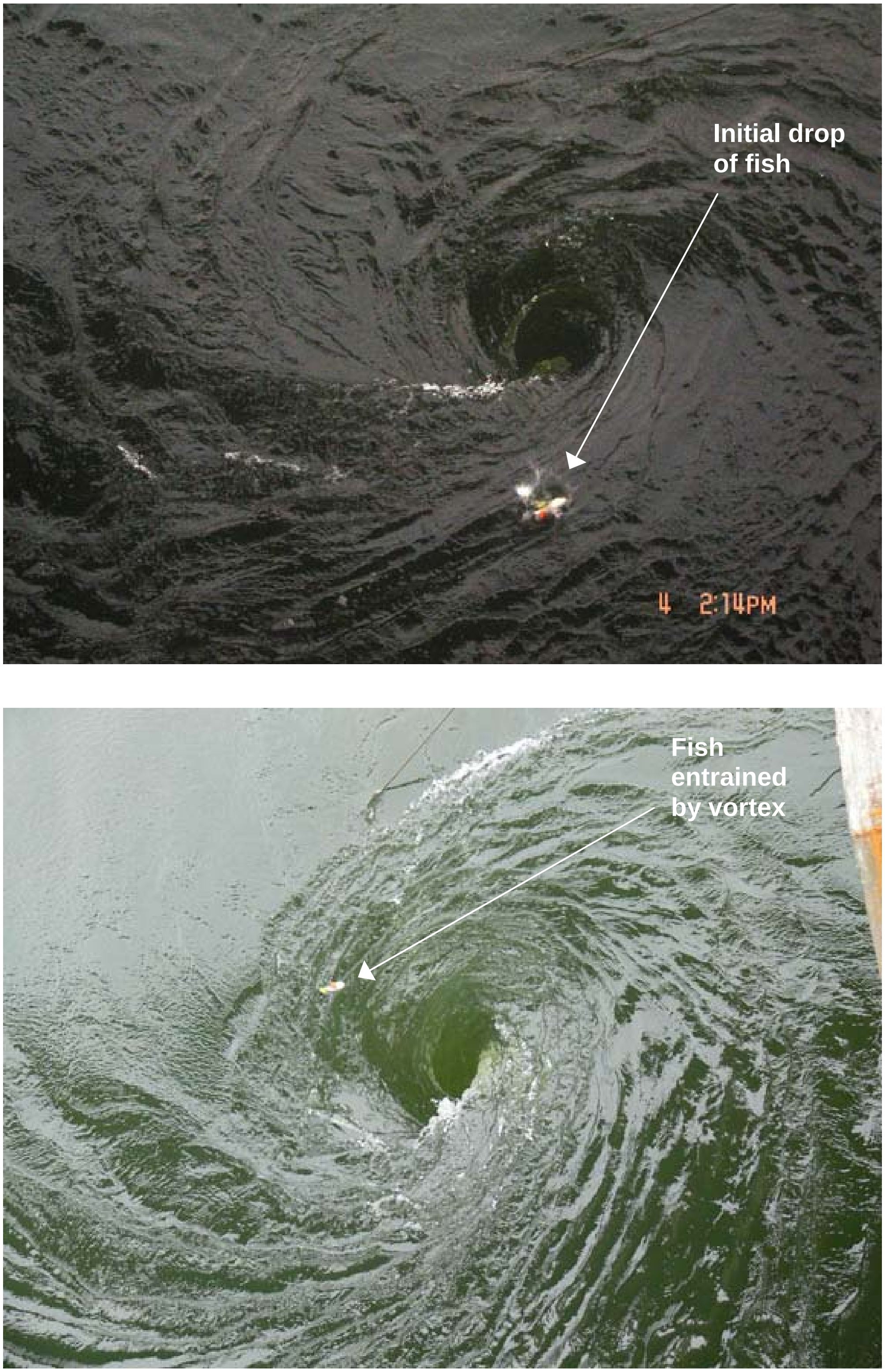


Figure 2-10 Juvenile fish release by hand into a vortex in the forebay of Spillbay 17 at John Day Dam, March-April 2008.

2.4 Fish Recapture

Both treatment and control fish were retrieved from the tailwater by several (three or four) boat crews. Boat crews were notified of the radio tag frequency of each fish upon its release. Only crew members trained in fish handling retrieved tagged fish.

Radio signals were received on a Yagi or loop antenna coupled to a receiver. The radio signal transmission enabled the boat crew(s) to follow the movement of each fish after spillway passage, and position the boat for quick retrieval when the HI-Z tag buoyed the fish to the surface. The boats maintained a safe distance downstream of the turbulent water from the spillbay. Any fish with active radio tags that failed to surface was tracked for about 30 minutes, and then periodically to ascertain if fish are displaying movement patterns typical of emigrating smolts or that of a predator. Recaptured fish were placed into an on-board holding facility, and the tag(s) removed. Each fish was examined for scale loss and injuries and assigned codes relative to descriptions presented in Table 2-7.

Recaptured fish were transferred in 5 gal pails to an on-shore holding pool for assessment of long-term effects (48 h). Each day's specimens for a given trial were held in the same or similar pool. Pools were continuously supplied with ambient river water and shielded to prevent fish escapement and potential avian predation.

2.5 Classification of Recaptured Fish

The immediate status of an individual fish was designated as alive, dead, predation, dislodged inflated tag(s) recovered, or unknown. The following criteria have been established to clearly define these designations: 1) alive--recaptured alive and remained so for 1 h; 2) alive--fish does not surface but radio signals indicate movement patterns typical of emigrating juveniles; 3) dead--recaptured dead or dead within 1 h of release; 4) dead--only inflated tag(s) are recovered without the fish and telemetric tracking or the manner in which tags surfaced is not indicative of predation; 5) unknown--neither tags nor fish are recovered and radio signals are not received or only briefly and a more detailed status cannot be ascertained; and 6) predation--fish are either observed being preyed upon, the predator is buoyed to the surface, distinctive bite marks are present, or subsequent radio telemetric tracking and/or dislodged tag recovery indicate predation (*i.e.*, rapid movements of tagged fish in and out of turbulent waters or sudden appearance of fully inflated dislodged tags). In estimation of passage survival, these fish are treated as dead.

Mortalities occurring > 1 h post-passage were considered 48 h mortalities. However, fish were evaluated at intervals of approximately 12 h. Dead fish were identified by the numbered VI tag or fin clip (if VI tag is missing), examined for descaling and injury, and necropsied to determine the potential cause of death.

Injuries were evaluated immediately following recapture, and later during a detailed examination after completion of the 48 h holding period. Injury and descaling were categorized by type, extent, and area of body. Photographs of injured fish were taken. Fish without any visible injuries that were not actively swimming will be classified as "loss of equilibrium". This condition has been noted in past studies and often disappears within 10 to 15 minutes after recapture.

The re-examination of immobilized fish minimized the need for extensive handling and associated stress upon immediate recapture. The initial examination allowed detection of some injuries, such as bleeding and minor bruising that may not be evident after 48 h due to natural healing processes.

A malady category was established to include fish with visible injuries, scale loss (≥ 20% on either side), or loss of equilibrium. Fish without maladies are designated "malady-free". This malady-free metric was established to provide a standard way to present a rate depicting how a specific route affects the condition of passed fish. Malady-free, the absence of maladies was chosen so that this metric may be more comparable to survival; however, the malady-free metric is based solely on fish

Table 2-7

Condition codes assigned to fish and dislodged balloon tags for fish passage survival studies.

Status Codes	**Description**		
*	Turbine/passage-related malady		
4	Damaged gill(s): hemorrhaged, torn or inverted		
5	Major scale loss, > 20% scale loss per side		
6	Severed body or nearly severed		
7	Decapitated or nearly decapitated		
8	Damaged eye(s): hemorrhaged, bulged, ruptured or missing		
9	Damaged operculum: torn, bent		
A	No visible marks on fish		
B	Flesh tear at tag site(s)		
C	Minor scale loss, < 20%		
E	Laceration(s): tear(s) on body or head (not severed)		
F	Torn isthmus		
G	Hemorrhaged, bruised head or body		
H	LOE		
K	Failed to enter system		
L	Fish likely preyed on (telemetry, circumstances relative to recapture)		
M	Substantial bleeding at tag site		
P	Predator marks		
Q	Other information		
R	Replaced due to unrecoverable conditions		
T	Trapped inside tunnel/gate well		
V	Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin		
W	Abrasion / Scrape		
Survival Codes			
1	Recovered alive		
2	Recovered dead		
3	Unrecovered – tag & pin only		
4	Unrecovered – no information or brief radio telemetry signal		
5	Unrecovered – trackable radio telemetry signal or other information		
Dissection Codes			
1	Shear	F	Hemorrhaged internally
2	Mechanical	J	Major
3	Pressure	L	Organ displacement
4	Undetermined	M	Minor
5	Mechanical/Shear	N	Heart damage, rupture, hemorrhaged
6	Mechanical/Pressure	O	Liver damage, rupture, hemorrhaged
7	Shear/Pressure	R	Necropsied, no obvious injuries
B	Swim bladder ruptured or expanded	S	Necropsied, internal injuries
D	Kidneys damaged (hemorrhaged)	T	Tagging/Release
E	Broken bones obvious	W	Head removed; i.e., otolith

physically recaptured and examined. Additionally, the malady-free estimate in concert with site-specific hydraulic and physical data can provide insight into what passage conditions may provide safer fish passage.

Two additional metrics that incorporate survival and maladies were also calculated: (1) a conditional malady-free estimate which is conditional on 48 h survival, and (2) a joint probability of surviving passage and being malady-free. Both of these metrics incorporate data from recovered and un-recovered fish and have been used in recent direct injury/survival studies (Normandeau *et al*. 2007, 2008).

Visible injuries, scale loss, and loss of equilibrium (LOE) were be categorized as minor or major, based on laboratory studies by PNNL *et al.* (2001) and Normandeau's field observations. These are as follows:

- A fish with only LOE is classified as major if the fish dies within 1 h; if it survives or dies beyond 1 h, it is classified as minor.
- A fish with no visible internal or external maladies is classified as a passage-related major injury if the fish dies within 1 h; if it dies beyond 1 h, it is classified as a non-passage related minor injury.
- Any minor injury that leads to death within 1 h is classified as a major injury; if it lives or dies after 1 h, it remains a minor injury.
- Hemorrhaged eye: minor if less than 50%; major if 50% or more.
- Deformed pupil(s): major.
- Bulged eye: major unless only slightly bulged; minor if slight bulge.
- Bruises (size-dependent): major if 10% or more of fish body per side; otherwise minor.
- Inverted or bleeding gills or gill arches: major.
- Operculum tear at dorsal insertion: major if 5 mm or greater; otherwise minor.
- Operculum folded under or torn off: major.
- Scale loss: major if 20% or more of fish per side; otherwise minor.
- Scraping (damage to epidermis): major if 10% or more per side of fish; otherwise minor.
- Cuts and lacerations: generally classified as major. Small flaps of skin or skinned snouts: minor.
- Internal hemorrhage or rupture of kidney, heart or other internal organs and/or damaged spinal column resulting in death at 1 to 48 h, major.
- Multiple injuries: use worst injury.

The disposition of individual fish is presented in Appendix C-1.

2.6 Spillway Hydraulic Conditions

The volume of water spilled through the Spillbay 16 and Spillbay 17 depended primarily on the forebay elevation; crest elevation of the TSW and the distance Spillbay 17 tainter gate was opened (Table 2-3). Forebay elevation was maintained near 264 fmsl for the tests; the crest elevation of the TSW (250 fmsl) remained constant during the tests resulting in a discharge of approximately 9.7 through the TSW. The tainter gate in Spillbay 17 was opened 4.5 stops (3.6 ft) providing a discharge of 6.2 kcfs. Spillbays 14, 15, and 18 were also opened to provide training flow (Table 2-3). The hydraulic conditions at the TSW are shown in Figure 2-5.

The estimated velocity of the spill jet at the tailwater surface for the TSW and Spillbay 17 was approximately 74 ft/s during testing. This is typical for most ACOE hydroelectric dams in the Columbia River Basin. Laboratory studies suggest that these velocities exceed those capable of inflicting injury/mortality (approximately 58 ft/s) on fish when discharged into water surface without hard objects (Neitzel *et al.* 2000). Fish may begin to suffer injuries if discharged onto hard objects at velocities ≥ 20 ft/s (Bell *et al.* 1972).

2.7 Statistical Analysis

Statistical Analysis was conducted and presented by Drs. Richard Townsend and John Skalski.

2.7.1 Estimation of passage survival

Originally, a joint release-recapture model was planned to be used to estimate both 1 and 48 h passage survival through each spillbay route with a common control group. However, 100% of the control fish were recovered alive and all test fish were recovered, regardless of fate. The consequence of this event reduced the analysis to a product binomial likelihood just for the treatment groups. The joint likelihood can be written as

$$L = \prod_{i=1}^{5}\prod_{j=1}^{2}\left[\binom{R_{ij}}{a_{ij}}\tau_{ij}^{a_{ij}}\left(1-\tau_{ij}\right)^{R_{ij}-a_{ij}}\right] \qquad (1)$$

where

R_{ij} = number of fish released for the i^{th} block $(i=1,\ldots,5)$, j^{th} treatment (j = 1, 2);

a_{ij} = number of fish recovered alive for the i^{th} block $(i=1,\ldots,5)$, j^{th} treatment (j = 1, 2);

d_{ij} = number of fish recovered dead for the i^{th} block $(i=1,\ldots,5)$, j^{th} treatment (j = 1, 2);

τ_{ij} = passage survival probability for the i^{th} block $(i=1,\ldots,5)$, j^{th} treatment (j = 1, 2).

Maximum likelihood estimates were then

$$\hat{\tau}_{ij} = \frac{a_{ij}}{R_{ij}} \qquad (2)$$

with associated variance estimators

$$\widehat{\text{Var}}\left(\hat{\tau}_{ij}\right) = \frac{\hat{\tau}_{ij}\left(1-\hat{\tau}_{ij}\right)}{R_{ij}}. \qquad (3)$$

2.7.2 Malady-Free

The malady-free (MFE) estimate is based only on fish physically recaptured and examined for maladies. This estimate can be biased (possibly higher than reality) if a high percentage of the fish are not physically recaptured and the unrecaptured fish were actually injured. However, in many studies ≥ 98% of fish are recaptured.

$$MFE_i = \frac{c_{Ti} R_c}{R_{Ti} c_c}, \qquad (4)$$

Where:

c_{Ti} = total number of fish without maladies for treatment i (i = 1, …, n);

R_{Ti} = number of fish recovered that were examined for maladies for treatment i (i = 1, …, n);

c_c = number of control fish recovered without maladies.

R_c = number of control fish recovered that were examined for maladies.

2.7.3 Estimation of Conditional Probability of Being Malady-Free Given Alive at 48 h

The conditional probability of juvenile Chinook salmon being malady-free (i.e., no injury, scale loss ≥ 20% per side or loss of equilibrium) given it passed through the spillbay alive, i.e.,

$$\hat{\Psi} = 1 - \hat{P}\left(I \mid A\right) \qquad (5)$$

was also compared between treatments, where $P\left(I \mid A\right)$ = probability of malady, given a fish was alive. These values were estimated using a joint likelihood analogous to Eq. (1).

2.7.4 Estimation of Joint Probability of 48 h Survival and Being Malady-Free

In addition to the comparison of spillway passage survival (τ), the probabilities juveniles passed through the spillbay malady-free and alive was compared between the test conditions. The probability of a fish being alive and malady-free $(\hat{\theta})$ could be reduced to two conditionally independent components, i.e.,

$$\hat{\theta} = \hat{\tau} \cdot \hat{\Psi}, \qquad (6)$$

each of which was analyzed separately along with their joint contribution. The variance of $\hat{\theta}$ was estimated by

$$\widehat{\text{Var}}\left(\hat{\theta}\right) = \hat{\Psi}^2 \cdot \widehat{\text{Var}}\left(\hat{\tau}\right) + \hat{\tau}^2 \cdot \widehat{\text{Var}}\left(\hat{\Psi}\right) - \widehat{\text{Var}}\left(\hat{\tau}\right) \cdot \widehat{\text{Var}}\left(\hat{\Psi}\right), \qquad (7)$$

where $\widehat{\text{Var}}\left(\hat{\Psi}\right) = \dfrac{\hat{\Psi}\left(1 - \hat{\Psi}\right)}{k}$ (8)

and where k = number of fish alive at 48 h. In the case where all controls were recovered alive and malady-free, $\hat{\theta}$ was reduced to a binomial proportion for the treatment fish recovered alive and malady-free.

3.0 RESULTS

3.1 Recapture Rates

Recapture rates (physical retrieval of alive and dead fish) for both treatment groups were high ranging from 98.7 to 100% for the treatment and 100% for the controls (Table 3-1). The recapture rate for the few (25) fish passed via the vortex was considerably lower (84%) only tags were recaptured on 4 (16%) of these fish. Only tags (1%) were also recaptured for three of the TSW passed fish. These fish were assigned a dead status. Only one fish (TSW) from all the releases was actually recaptured dead.

3.2 Retrieval Times

The average retrieval time for the treatment groups was 14 min with a range of 2-212 min compared to an average of 5 min and a range of 1 to 58 min for control fish (Figure 3-1). The time to recapture treatment fish was longer because the recapture boat crews had to remain approximately 500 yards downstream of the turbulent discharge from the spillbays. There was little turbulence at the discharge from the Juvenile Fish Facility bypass pipe to delay control recapture.

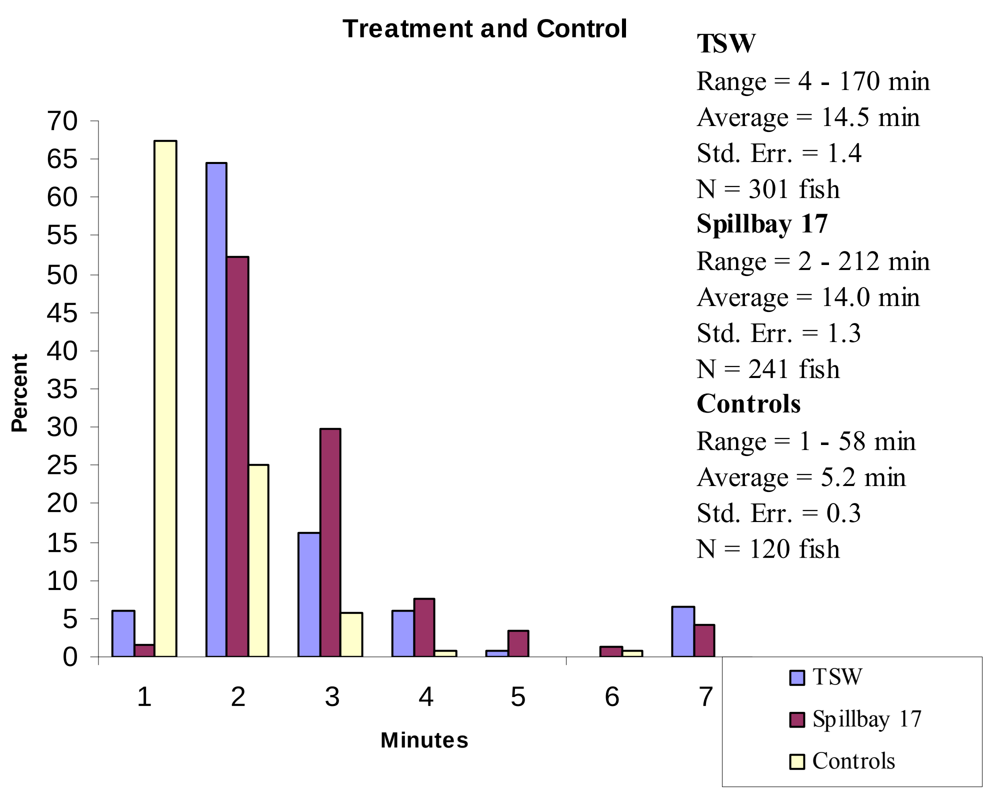


Figure 3-1 Frequency distribution of recapture times (minutes) of treatment and control juvenile Chinook salmon passed through TSW and Spillbay 17 near mid depth. Control fish were released via the Juvenile Fish Facility bypass pipe at John Day Dam, March-April 2008.

Table 3-1

Summary tag-recapture data for juvenile Chinook salmon passed through TSW and Spillbay 17 at mid depth. Control fish released via the Juvenile Fish Facility (JFF) bypass pipe at John Day Dam, March-April 2008.

Proportions given in parentheses.

	Spillbay 16 TSW		Spillbay 17				Control	
	Mid		Mid		Vortex*		(JFF)	
Discharge (kcfs)	**9.7**		**6.2**		**6.2**			
Number Released	305		241		25		12	
Number Recaptured alive	300	(0.984)	241	(1.000)	21	(0.840)	120	(1.000)
Number Recaptured dead	1	(0.003)	0	(0.000)	0	(0.000)	0	(0.000)
Number Assigned dead**	4	(0.013)	0	(0.000)	4	(0.160)	0	(0.000)
Dislodged Tags	3	(0.010)	0	(0.000)	4	(0.160)	0	(0.000)
Stationary Signal	1	(0.003)	0	(0.000)	0	(0.000)	0	(0.000)
Number Unknown	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)
Number Held	300	(0.984)	241	(1.000)	21	(0.840)	120	(1.000)
Number Alive 48 h	299	(0.980)	241	(1.000)	20	(0.800)	120	(1.000)

* Fish released at surface into vortex in forebay of Spillbay 17

** Primarily fish where only HI-Z tag(s) recaptured

3.3 Passage Survival

The recoveries and 1h and 48 h alive/dead status for each spillbay treatment are displayed in Table 3-2. All fish released as a control or into Spillbay 17 were recaptured and alive at the 48 h. There were no undetermined fates for the treatment fish (*i.e.*, all either alive or dead). As the estimated survival for each of the replicates through Spillbay 17 is 100%, all the estimated variance is present only in TSW replicates, rendering an analysis of deviance invalid.

Table 3-2 Counts of juvenile Chinook salmon released for each spillbay and the number recovered alive and dead at 1 h and 48 h or unknown, at John Day Dam, March-April 2008.

		Spillbay 16 (TSW) Status at 1 h			Spillbay 17 (Conventional) Status at 1 h		
Block	Date	Alive	Dead	Unknown	Alive	Dead	Unknown
1	3/31/08	5	0	0	5	0	0
2	4/01/08	72	1	0	68	0	0
3	4/02/08	83	1	0	73	0	0
4	4/03/08	96	3	0	75	0	0
5	4/04/08	44	0	0	20	0	0
		Status at 48 h			Status at 48 h		
Block	Date	Alive	Dead	Unknown	Alive	Dead	Unknown
1	3/31/08	5	0	0	5	0	0
2	4/01/08	71	2	0	68	0	0
3	4/02/08	83	1	0	73	0	0
4	4/03/08	96	3	0	75	0	0
5	4/04/08	44	0	0	20	0	0

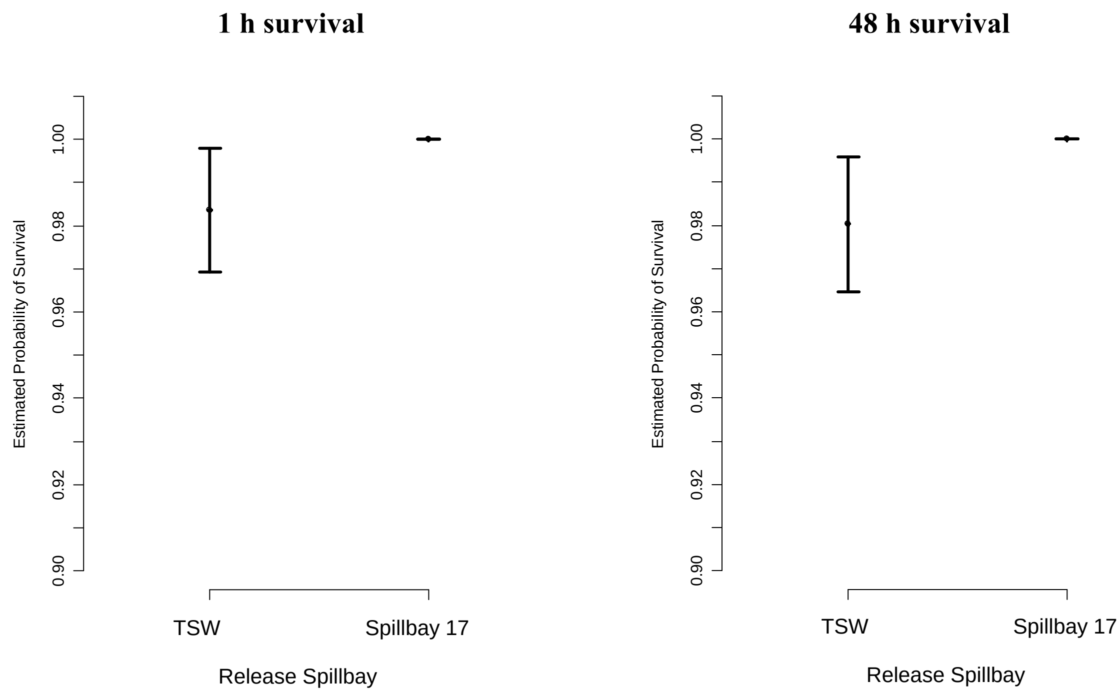
One hour passage survival for the control releases and those that passed through the Spillbay 17 was $\hat{\tau}$ = 1.0000 ($\widehat{SE}$ = 0) for all 5 replicates, and ranged from 0.9697 to 1.0000 for TSW. A Chi-square test for homogeneity allowed pooling of the replicate releases at TSW (P($\chi_4^2 \geq 2.1424$) = 0.7096). A pooled estimate for the TSW passage was $\hat{\tau}$ = 0.9836 ($\widehat{SE}$ = 0.0073). TSW passage survival was tested against Spillbay 17 passage survival (H_0: $\hat{\tau}_{TSW} = \hat{\tau}_{conventional}$) with a nonparametric binomial sign test (Sheskin 2000), and was significantly different (*P* = 0.0313) and less than Spillbay 17.

Only one mortality occurred between 1 and 48 h after recovery (TSW on 1 April), so passage survival for the control releases and those that passed through Spillbay 17 was $\hat{\tau}$ = 1.0000 ($\widehat{SE}$ = 0) for all 5 replicates. The pooled survival for TSW was $\hat{\tau}$ = 0.9803 ($\widehat{SE}$ = 0.0080). Passage survival through the TSW was again tested with the sign test, and was significantly different (*P* = 0.0313) and less than Spillbay 17. Table 3-3 and Figure 3-2 summarize the 1 h and 48 h survival results.

Table 3-3 Estimated 1 h and 48 h passage survival of juvenile Chinook salmon through TSW and Spillbay 17 at John Day Dam, March-April 2008. Standard errors are in parentheses. Because of the 100% observed passage survival at Spillbay 17, standard error is estimated to be zero.

Spillbay	1 h $\hat{\tau}(\widehat{SE})$	48 h $\hat{\tau}(\widehat{SE})$
TSW	0.9836 (0.0073)	0.9803 (0.0080)
17	1.0000 (0)	1.0000 (0)

Figure 3-2 Estimated 95% confidence intervals on 1 h and 48 h passage survival of juvenile Chinook salmon through TSW and Spillbay 17, John Day Dam, March-April 2008.



3.4 Conditional Probability of Being Malady-Free, Given Alive at 48 h

All recaptured juvenile Chinook salmon alive were examined for maladies (Table 3-4). All control fish were malady-free. Chi-square tests of homogeneity found similar malady rates across replicate releases at TSW (P($\chi_4^2 \geq 6.4056$) = 0.1708) and Spillbay 17 (P($\chi_4^2 \geq 1.5733$) = 0.8136). The analysis of deviance of the estimated conditional probability of being malady-free, given 48 h passage survival (Table 3-5) indicates that the effect of spillbay (*P* = 0.9096) was non-significant. The conditional probabilities that a fish would be malady-free for each of the two spillbay passage routes were quite similar (Table 3-6). Of the fish that survived to 48 h after passage, TSW had 96.7% ($\widehat{SE}$ =0.99%) of the fish malady-free and Spillbay 17 had 96.7% ($\widehat{SE}$ = 1.15%). A plot of the conditional probability of being malady-free given alive at 48 h by spillbay (Figure 3-3) illustrates considerable overlap of the 95% confidence intervals.

Table 3-4 Counts of juvenile Chinook salmon alive at 48 h and examined for maladies after passing through TSW and Spillbay 17, John Day Dam, March-April 2008.

			TSW Malady			Spillbay 17 Malady	
Block	Date	Alive	Not present	Present	Alive	Not present	Present
1	3/31/08	5	5	0	5	5	0
2	4/01/08	71	66	5	68	65	3
3	4/02/08	83	82	1	73	72	1
4	4/03/08	96	93	3	75	72	3
5	4/04/08	44	44	0	20	19	1

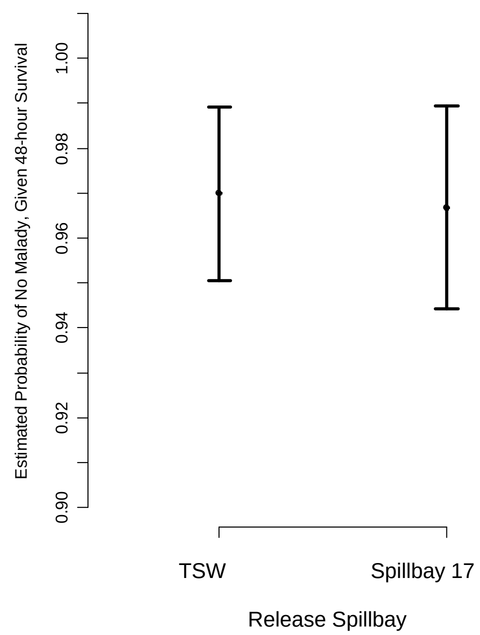
Table 3-5 Analysis of deviance for the conditional probability of a juvenile Chinook salmon of being malady-free given 48 h survival after passing through TSW and Spillbay 17, John Day Dam, March-April 2008.

Source	DF	Deviance	Mean deviance	F-test	P-value
$\text{Total}_{\text{Cor}}$	9	9.0558			
Block	4	6.1433	1.5358		
Spillbay	1	0.0106	0.0106	0.0146	0.9096
Error	4	2.9019	0.7255		

Table 3-6 Estimated conditional probability for juvenile Chinook salmon of being malady-free, given 48 h survival, after passing through TSW and Spillbay 17, John Day Dam, March-April 2008. Standard errors are in parentheses.

Spillbay	P (No malady|alive at 48 h) ($\widehat{SE}$)
TSW	0.9699 (0.0099)
17	0.9668 (0.0115)

Figure 3-3 Estimated conditional probability with 95% confidence intervals of being malady-free, given 48 h survival, John Day Dam, March-April 2008.



3.5 Estimation of Joint Probability of 48 h Survival and Being Malady-Free

In Section 3.3, the estimated probability of recovering a fish was 1.0 (alive or dead fish), reducing the estimation of the probabilities of surviving passage under each of the treatment conditions without incurring a malady to a simple binomial proportion. This proportion was based on the observed fraction of treatment releases that were recovered alive and without malady. Chi-square tests of homogeneity found similar rates across replicate releases at TSW (P($\chi_4^2 \geq 7.3732$) = 0.1174) and Spillbay 17 (P($\chi_4^2 \geq 1.5733$) = 0.8136). Table 3-7 has the resulting counts by category for each trial. The analysis of deviance (Table 3-8) indicates that the effect of spillbay (P = 0.3131) was non-significant. The joint probability of surviving passage without incurring a malady was 0.967

($\widehat{SE}$ =0.0115) for Spillbay 17 and 0.951 ($\widehat{SE}$ =0.0124) for the TSW. Table 3-9 and Figure 3-4 summarize the results of the alive and injury-free passage rates.

Table 3-7 Counts of juvenile Chinook salmon released into TSW and Spillbay 17 and the numbers of alive and malady-free at 48 h, or dead (or assumed dead) and/or with a malady at John Day Dam, March-April 2008.

	TSW			Spillbay 17		
Block	Released	Alive w/o Malady	Dead and/or with malady	Released	Alive w/o Malady	Dead and/or with malady
1	5	5	0	5	5	0
2	73	66	7	68	65	3
3	84	82	2	73	72	1
4	99	93	6	75	72	3
5	44	44	0	20	19	1

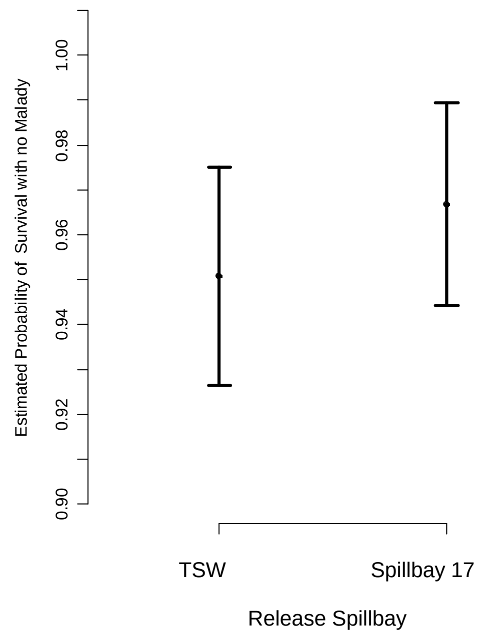
Table 3-8 ANODEV for the joint probability of 48 h survival and being malady-free, for juvenile Chinook salmon passed through TSW and Spillbay 17 at John Day Dam, March-April 2008.

Source	DF	Deviance	Mean deviance	F-test	P-value
$Total_{Cor}$	9	12.1129			
Block	4	7.6787	1.9197		
Spillbay	1	1.1060	1.1060	1.3292	0.3131
Error	4	3.3282	0.8321		

Table 3-9 Estimated joint probability of 48 h survival and being malady-free for juvenile Chinook salmon after passing through TSW and Spillbay 17 at John Day Dam, March-April 2008. Standard errors are in parentheses.

Spillbay	P(Survival and No malady) ($\widehat{SE}$)
TSW	0.9508 (0.0124)
17	0.9668 (0.0115)

Figure 3-4 Estimated joint probabilities of 48 h survival and being malady-free after passing through TSW and Spillbay 17 at John Day. Vertical lines indicate 95% confidence intervals, 2008.



3.6 Comparison of Spillbay 17, vortex release

3.6.1 Estimation of passage survival for the vortex release

Only one replicate of two fish was released into the vortex of Spillbay 17 on 4 April 2008, so this was compared to the corresponding release into Spillbay 17 at mid depth on the same day (Table 2-6). The corresponding release into TSW had 100% recovery and 48 h survival, with no maladies. The recoveries and 1 and 48 h alive/dead status for each release location are displayed in Table 3-10. All fish released at mid depth in Spillbay 17 were recaptured and were alive at 48 h.

Table 3-10 Counts of juvenile Chinook salmon released for each release depth and the number recovered alive and dead at 1 and 48 h or unknown at John Day Dam, 4 April 2008.

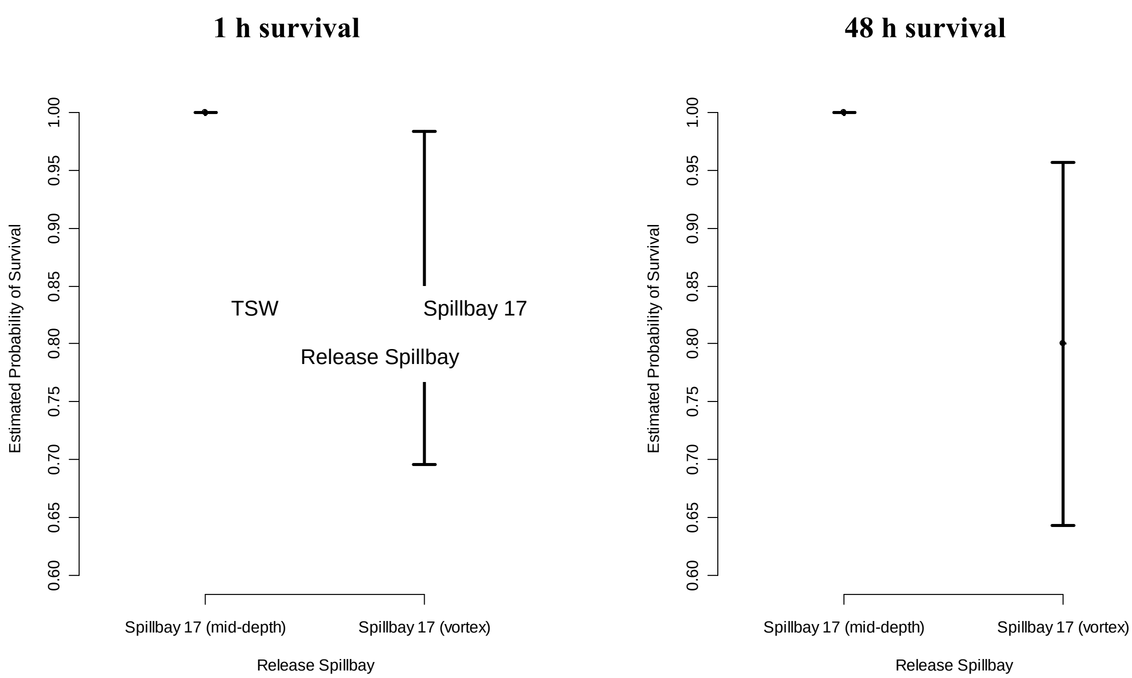
	Status at 1 h			Status at 48 h		
Spillbay	Alive	Dead	Unknown	Alive	Dead	Unknown
17 (mid depth)	20	0	0	20	0	0
17 (vortex)	21	4	0	20	5	0

Both 1 h and 48 h passage survivals for releases that passed through Spillbay 17 at mid depth were $\hat{\tau}$ = 1.0000 ($\widehat{SE}$ = < 0.0001) (Table 3-11). The 1 h passage survival for the vortex was $\hat{\tau}$ = 0.8400 ($\widehat{SE}$ = 0.0733) and 48 h passage survival dropped to $\hat{\tau}$ = 0.8000 ($\widehat{SE}$ = 0.0800). Assuming a binomial distribution for survival, the observed vortex passage survival was tested against the mid depth passage survival (H_0: mid depth survival = vortex survival), and found to significantly differ at both 1 h and 48 h (1 h: $P(\chi_1^2 \geq 3.5122) = 0.0609$; 48 h: $P(\chi_1^2 \geq 4.5000) = 0.0339$). Table 3-11 and Figure 3-5 summarize the passage survival through mid depth and vortex release locations at Spillbay 17.

Table 3-11 Estimated 1 h and 48 h passage survival of juvenile Chinook salmon through Spillbay 17 (mid depth and vortex) at John Day Dam, 4 April 2008. Standard errors are in parentheses.

Spillbay	1-hour $\hat{\tau}(\widehat{SE})$	48-hour $\hat{\tau}(\widehat{SE})$
17 (mid depth)	1.0000 (< 0.0001)	1.0000 (< 0.0001)
17 (vortex)	0.8400 (0.0733)	0.8000 (0.0800)

Figure 3-5 Estimated probability of 1 h and 48 h passage survival of juvenile Chinook salmon through Spillbay 17 (mid depth and vortex) at John Day Dam, 4 April 2008. Vertical lines indicate 95% confidence intervals.



3.6.2 Estimation of being malady-free, given alive at 48 h for vortex release

All alive recaptured juvenile Chinook salmon were examined for maladies (Table 3-12). All control fish were malady-free. The conditional probability that a fish would be malady-free for the vortex passage route was significantly different and lower (P($\chi_1^2 \geq 4.3290$) = 0.0375) than at mid depth (Table 3-13). Of the fish that survived to 48 h after passage, the mid depth release group had a $\hat{\Psi}$ = 0.9500 ($\widehat{SE}$ = 0.0487) probability of not incurring a malady, while the vortex group had $\hat{\Psi}$ = 0.7000 ($\widehat{SE}$ = 0.1025). A plot of the conditional probability by spillbay (Figure 3-6) illustrates slightly overlapping 95% confidence intervals for both passage routes.

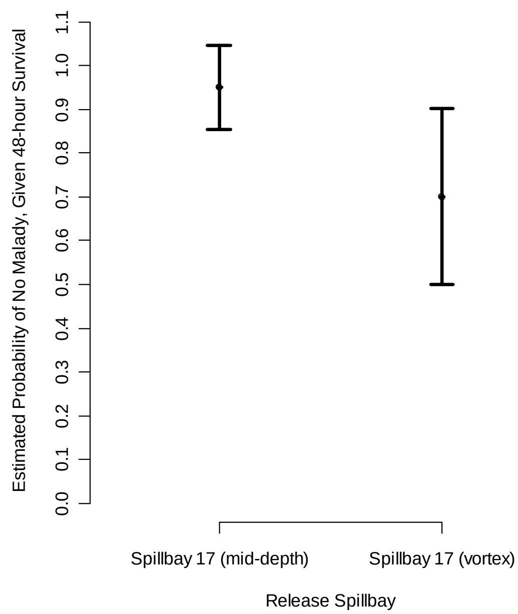
Table 3-12 Counts of juvenile Chinook salmon alive at 48 h and examined for maladies after passing through Spillbay 17 (mid depth and vortex) at John Day Dam, 4 April 2008.

		Malady	
Spillbay	Alive	Not present	Present
17 (mid depth)	20	19	1
17 (vortex)	20	14	6

Table 3-13 Estimated conditional probability for juvenile Chinook salmon of being malady-free, given 48 h survival, after passing through Spillbay 17 (mid depth and vortex) at John Day Dam, 4 April 2008. Standard errors are in parentheses.

Spillbay	P(No malady|alive at 48 h) ($\widehat{SE}$)
17 (mid depth)	0.9500 (0.0487)
17 (vortex)	0.7000 (0.1025)

Figure 3-6 Estimated conditional probability of being malady-free, given 48 h survival, after passing through Spillbay 17 (mid depth and vortex) at John Day Dam, 4 April 2008. Vertical lines indicate 95% confidence intervals.



3.6.3 Estimation of joint probability of 48 h survival and being malady-free for vortex release

The analysis in this section is applicable to 48 h survival after passage. Table 3-14 presents counts by category for each trial. The joint probability of surviving passage without incurring a malady was 0.9500 ($\widehat{SE}$ = 0.0487) for mid depth Spillbay 17 and 0.5600 ($\widehat{SE}$ = 0.0993) for the vortex release (Table 3-15 and Figure 3-7). These sites were significantly different (P($\chi_1^2 \geq 8.6420$) = 0.0033).

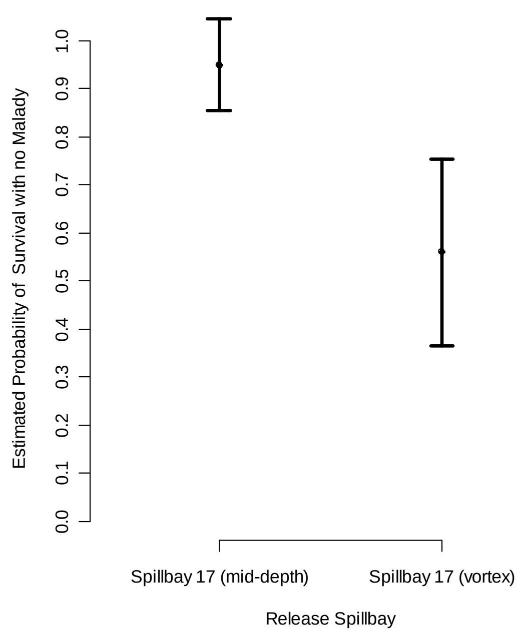
Table 3-14 Counts of juvenile Chinook salmon released into Spillbay 17 (mid depth and vortex) and the numbers of alive and malady-free at 48 h, or dead and/or with a malady at John Day Dam, 4 April 2008.

Spillbay	Released	Alive w/o Malady	Dead and/or with malady
17 (mid depth)	20	19	1
17 (vortex)	25	14	11

Table 3-15 Estimated joint probability of 48 h survival and being malady-free for juvenile Chinook salmon after passing through Spillbay 17 (mid depth and vortex) at John Day Dam, 4 April 2008. Standard errors are in parentheses.

Spillbay	P(Survival and No malady) ($\widehat{SE}$)
17 (mid depth)	0.9500 (0.0487)
17 (vortex)	0.5600 (0.0993)

Figure 3-7 Estimated 95% confidence intervals on joint probabilities of 48 h passage survival and being malady-free for the two release sites at Spillbay 17 (mid depth and vortex) on juvenile Chinook salmon at John Day Dam, 4 April 2008.



3.7 Overall Comparison of Survival and Malady-Free

Table 3-16 provides a summary for quick reference of the 48 h survival, conditional probability of being malady-free given alive at 48 h, and joint probability of 48 h survival being malady-free. Comparison of the TSW with that of Spillbay 17 found passage survival ($\hat{\tau}$) to be less at the TSW, but conditional injury rates were not different (P = 0.9096). The joint probability of surviving injury-free through the TSW and Spillbay 17 were not different (P = 0.3131). The comparison of the single vortex release to the mid depth release at Spillbay 17 indicates a much lower passage survival and malady-free probabilities. The survival and malady-free probabilities for the vortex release into Spillbay 17 are based on one replicate release, while the other two estimates at TSW and Spillbay 17 are based on five replicates.

Table 3-16

48 h survival ($\hat{\tau}$), conditional probability of being malady-free given alive at 48 h ($\hat{\psi}$), and joint probability of 48 h survival and being malady-free ($\hat{\theta}$) for TSW and Spillbay 17 (mid depth and vortex) at John Day Dam, March-April 2008. Standard errors are in parentheses.

Spillbay	$\hat{\tau}(\widehat{SE})$	$\hat{\psi}(\widehat{SE})$	$\hat{\theta}(\widehat{SE})$
TSW	0.9803 (0.0080)	0.9699 (0.0099)	0.9508 (0.0124)
17 (Mid depth)	1.0000 (< 0.0001)	0.9668 (0.0115)	0.9668 (0.0115)
17 (Vortex)	0.8000 (0.0800)	0.7000 (0.1025)	0.5600 (0.0993)

3.8 Malady Rates, Type, Severity, and Probable Cause

Visible injury and malady rates observed on recaptured fish given below are based on the total number of fish recaptured and examined not on the total number of fish released and refer only to those attributed to passage (Table 3-17, Appendix Table B-2 and B-3). Control fish sustained no visible injuries or maladies thus no adjustments for control were necessary. A total of 15 (2.8%) out of the 542 mid passed treatment fish examined displayed passage related injuries and an additional 2 (0.4%) fish displayed only loss of equilibrium (LOE), with no fish having only scale loss. Malady rates (injury plus LOE) were similar for mid passed TSW (3.0%) and Spillbay 17 (3.3%) fish.

Incidence of passage induced maladies was greater for vortex passed fish (Table 3-17). Four of the 21 (19%) recaptured vortex passed fish were visibly injured and 2 (9.5%) additional fish displayed only LOE.

Eye damage, which included hemorrhage, bulge, and/or pupil rupture, was the dominant injury for both mid release tests (Table 3-18, Figure 3-8, and Appendix Table B-4). Some 1.3% and 2.1% of the TSW and Spillbay 17 mid depth passed fish incurred eye damage, respectively. Eye damage (19.0%) was also the dominant injury for vortex passed fish. Few (< 1%) fish incurred other types of injuries.

Based on the severity classifications presented in Section 2.5, most (12 of 17) of maladies for mid depth passed fish at TSW and Spillbay 17 were classified as minor (Table 3-19). Most (10 of 17) maladies were attributed to shear forces (Table 3-19). Examples of shear-related maladies are shown in Figure 3-8. Maladies were also classified as minor for most (4 of 6) of the vortex passed fish that had visible injuries or loss of equilibrium (Table 3-19). Again, most of these maladies were shear-induced.

Table 3-17

Summary malady data for juvenile Chinook salmon released through TSW and Spillbay 17 at mid depth. Control fish released via the Juvenile Fish Facility bypass pipe at John Day Dam, March-April 2008.

Proportions given in parentheses.

	TSW		Spillbay 17					
Passage Location	**Mid**		**Mid**		**Vortex**		**Control**	
Number released	305		241		25		120	
Number examined	301	(0.987)	241	(1.000)	21	(0.840)	120	(1.000)
Passage related maladies	10	(0.033)	8	(0.033)	6	(0.240)	0	(0.000)
Visible injuries	8	(0.026)	7	(0.029)	4	(0.160)	0	(0.000)
Loss of equilibrium only	1	(0.003)	1	(0.004)	2	(0.080)	0	(0.000)
Scale loss only	--		--		--		--	
Without maladies	290	(0.951)	233	(0.967)	14	(0.560)	120	(1.000)
Without maladies that died*	1		0		1		0	
Malady-free rate	97.01%		71.43%		96.68%			
95% CI (+/-)	1.900		19.300		2.300			

*Fish dead due to non-passage related malady

Table 3-18

Summary of visible injury types and rates (passage induced) observed on recaptured juvenile Chinook salmon released through TSW and Spillbay 17 at mid depth. Control fish released via the Juvenile Fish Facility bypass pipe at John Day Dam, March-April 2008. Proportions given in parentheses.

Passage Location	No. Released	No. Examined		Passage Related Visibly Injured No. of fish		Injury Type: Eye(s) Hemorrhaged, Bulged, Ruptured,		Injury Type: Operculum/Gills Hemorrhaged Torn, Scraped,		Injury Type: Body/Head Cut, Torn, Scraped		Injury Type: Body/Head Hemorrhaged, Bruised	
						TSW							
Mid	305	301	(0.987)	8	(0.027)	4	(0.013)	1	(0.003)	1	(0.003)	2	(0.007)
						Spillbay 17							
Mid	241	241	(1.000)	7	(0.029)	5	(0.021)	1	(0.004)	0	(0.000)	1	(0.004)
						Spillbay 17							
Vortex	25	21	(0.840)	4	(0.190)	4	(0.190)	0	(0.000)	0	(0.000)	0	(0.000)
						Control							
	120	120	(1.000)	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)

TSW

Spillbay 17

17 Vortex

Figure 3-8 Examples of eye injuries sustained by juvenile Chinook salmon passed through TSW (top two photos), Spillbay 17 (middle two photos), and Vortex (bottom photo), John Day Dam, March-April 2008.

Table 3-19

Probable sources and severity of maladies observed on recaptured juvenile Chinook salmon released through TSW and Spillbay 17 at mid depth. Control fish released via the Juvenile Fish Facility bypass pipe at John Day Dam, March-April 2008. Proportions given in parentheses.

Passage Location	No. of Fish Examined	Total With Maladies		Probable Injury Source: Mechanical		Probable Injury Source: Shear		Probable Injury Source: Mechanism Undetermined		Severity: Minor		Severity: Major	
						TSW							
Mid	301	9	(0.030)	3	(0.010)	5	(0.017)	1	(0.003)	6	(0.020)	3	(0.010)
						Spillbay 17							
Mid	241	8	(0.033)	2	(0.008)	5	(0.021)	1	(0.004)	6	(0.025)	2	(0.008)
						Spillbay 17							
Vortex	21	6	(0.286)	0	(0.000)	4	(0.190)	2	(0.095)	4	(0.190)	2	(0.095)
						Control							
	120	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)

4.0 PRINCIPAL FINDINGS AND CONCLUSIONS

The statistical criteria set forth for the experiment were met. The precision (ε) on all estimates of survival and malady probabilities was within ≤ ± 0.025, 95% of the time and differences of ≥ 5% between estimates were detectable 95% of the time. The estimated 48 h direct survival was 0.9803 (SE = 0.0080) for TSW released fish and 1.000 (SE < 0.0001) for Spillbay 17 released fish. These two estimates (Δ = 0.0197) were significantly different (P = 0.0313). The conditional probability of being malady-free given alive at 48 h was 0.9699 (SE = 0.0099) for TSW released fish and 0.9668 (SE = 0.0115) for Spillbay 17 released fish. The joint probability of 48 h survival and being malady-free followed the same trends with respective values of 0.9508 (SE = 0.0124) and 0.9668 (SE = 0.0115). The respective malady estimates for TSW and Spillbay 17 passed fish were not significantly (P ≥ 0.3) different.

The survival and malady-free estimates for a supplemental group (25) of fish passed through a vortex in Spillbay 17 were much lower. The 48 h survival estimate was 0.8000 (SE = 0.0800) and the malady metrics were 0.7000 (SE = 0.1025) and 0.5600 (SE = 0.0993) for conditional and joint probability values.

The results of the present study apply to only mid depth passed fish and may not be extended to other depths because only one depth was tested. However, evidence from several direct injury and malady studies at spillways on the Lower Snake and Columbia River Dams (Normandeau Associates, Inc. and Skalski 2005 and 2006; Normandeau 2004, Normandeau et al 2007 and 2008, Heisey *et al.* 2008) indicate that the site-specific characteristics (*e.g.*, spillway slope and angle of the spill jet intercepting the flow deflectors) and entrainment depth may influence the survival and post-passage condition of salmonid smolts. Steeper spillbay chutes and higher intercept angles at the flow deflectors appear to have deleterious effects on the post-passage condition of juvenile salmon that pass deep within the discharge jet. Fish that passed close to the ogee of a conventional Ice Harbor Dam spillbay with a 55° deflection angle had injury rates of 24.1 to 28.7% compared to 6.9 to 9.7% for fish released higher in the water column. The contrasts to an injury rate of only 1.4% for fish passed deep within the discharge jets at McNary spillbays with a deflection angle of 42.5° (Normandeau *et al.* 2008). Mid discharge jet passed fish at McNary had injury rates of 0.4 and 2.2%. Fish passed deep and near mid discharge jet through spillbays equipped with TSW's and McNary Dam also had low injury rates, 0.7 to 2.9%.

The deflection angle 45° at John Day is closer to that at McNary and may be more benign in deep passed fish; however, this 45° deflection angle may still be deleterious for deep passed fish based on direct injury tests at Little Goose spillbays with the same deflection angle. The injury rate was 10.1% and 2.3% for juvenile salmon released 3 and 8 ft above the crest of Spillbay 2 (Normandeau *et al.* 2007). Releasing fish deeper in the TSW at John Day discharge would help determine if the angle at the spillbay chute or possible other factors may negatively affect deep passed fish.

The potential effect of depth on post-passage fish condition may have practical implications related to naturally migrating smolts passing the TSW and conventional spillbays at John Day Dam. Further evaluation incorporating vertical fish distribution at John Day Dam spillbays may be needed to estimate the overall impact of spillway passage on fish.

Sensor fish data, collected by Battelle, Pacific Northwest Division, indicated trends similar to the HI-Z tagged live fish released through the TSW and Spillbay 17. A separate report describing the results of sensor fish releases is being submitted by PNNL.

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APPENDIX TABLE A

STATION PARAMETERS

APPENDIX TABLE B-1

DAILY TAG RECAPTURE

APPENDIX TABLE B-2

MALADY DATA

APPENDIX TABLE B-3

48 H SURVIVAL/MALADY DATA

APPENDIX TABLE B-4

INCIDENCE OF INJURY/MALADY

APPENDIX TABLE C

INDIVIDUAL FISH DISPOSITION